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AGRICULTURAL EXPERIMENT STATION
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IMPERIAL BUREAU OF MYCOLOGY

Division of Plant Pathology

The Rhizoctonia Disease of Potatoes

by

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THE RHIZOCTONIA DISEASE OF POTATOES

by B. F. Dana

INTRODUCTION

The investigations of potato Rhizoctonia reported here have been confined chiefly to a study of symptoms and effects and control practices. The large irrigated area devoted to potatoes has made desirable some experiments and study in the irrigated sections but the bulk of the work has been carried out on the College Farm at Pullman where dry farming conditions prevail. The problems of the home gardener, the commercial grower and the seed producer have been considered and partial solutions for some of their problems may be advanced.

The period covered by the studies presented in this paper has included practically all of the past ten years. During this time numerous and important contributions have been made to the American literature on potato diseases. Since the paper of Orton in 1914 (51) on potato diseases, the importance of the virus diseases has been established and additional information is continually appearing. In this process the Rhizoctonia disease has found its place and we may more certainly characterize some of the symptoms of the disease and differentiate between them and certain similar symptoms found among the virus diseases. The data presented in this paper are not complete but an attempt will be made to make comparisons with results of studies by other workers.

TERMINOLOGY AND NOMENCLATURE

Popular Names

Certain popular names have been applied to this disease by growers and others such as, scurf, black scurf, stem rot, little potato disease, rosette, russet scab, blight, scab, black speck, black speck scab and black scab. Many of these names are distinctive for a certain phase of the disease only and are sometimes misleading in that they emphasize but a part of the symptoms that have been described for the disease. The majority of writers at the present time are using the term, "Rhizoctonia disease," to designate the trouble in any or all of its phases. This term is widely used in Washington by growers and consumers alike and does not seem objectionable because of its technical sound.

Nomenclature of the Fungus

Fortunately the nomenclature of the fungus causing the Rhizoctonia disease has been rather carefully reviewed by Duggar (20) and Peltier (54). **Rhizoctonia solani** Kühn is generally accepted for the sterile stage as found on potatoes and many other crops. The fungus was given the name **R. solani** by Kühn (35) in 1858. Some forty-five years later Rolfs (60) is credited with the finding of a spore stage which he proved to be identical with **Rhizoctonia solani** Kühn. Burt described this spore stage as **Corticium vagum** B. & C. var. **solani.** Further study has convinced Burt (9) that there is not even a varietal difference beween **Corticuim vagum** B. & C. and the form found on the potato hence he has dropped the variety **solani.** This is the same fungus that is known in European literature as **Hypochnus solani** Prill. & Del. which name Burt relegates to synonomy.

DISTRIBUTION AND IMPORTANCE

Distribution in Washington

The casual fungus is shown to be very widespread and abundant in Washington soils. Extensive isolations have not been made from soils but the fungus has been observed in all parts of the state. In addition, Rhizoctonia has been studied on an extensive range of

hosts from practically every part of the state and a list will be given in a later section of this paper. These investigations together with studies in the neighboring state of Idaho by Pratt (55) indicate a general occurrence of the Rhizoctonia in the Northwest.

The occurrence of the resting form of the parasite on seed potato stocks is very general. Stocks are improving in this respect but seed imported in the past from other states has shown a very general infection by sclerotia. The fungus carried on the seed, augmented by that already in the soil, has been responsible for almost universal occurrence of the disease in some form in the potato fields of the state (Fig. 1).

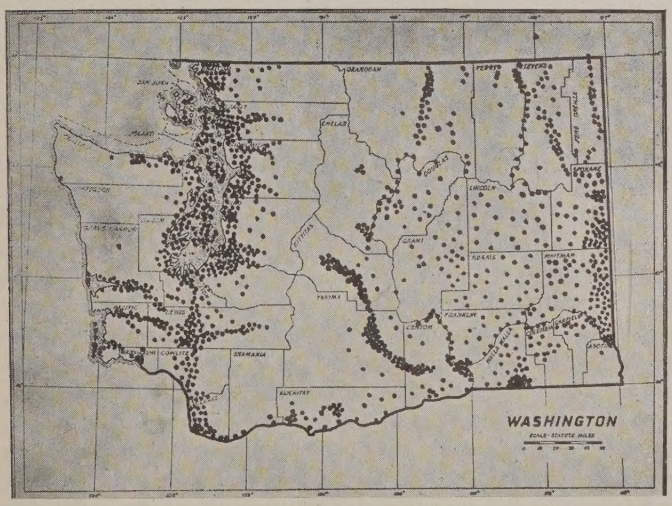

Fig. 1. Distribution of potato Rhizoctonia in Washington.

The prevalence of the disease has been emphasized by the large number of reports and specimens sent to the Experiment Station each year by growers and county agricultural agents from all parts of the state where potatoes are grown.

The distribution of the Rhizoctonia disease on potatoes is shown graphically in Figure 1 which was prepared from all the data available to the Division of Plant Pathology. The disease is shown to be more prevalent in the heavy potato producing sections of the state but is practically coextensive with potato production.

The Importance of the Rhizoctonia Disease

Until recent years it has been customary for growers and others in Washington to attribute poor yields, in the major part, to this disease. The Rhizoctonia fungus has been exceedingly conspicuous in many cases of poor or abnormal development of plants and was considered responsible for these abnormal effects largely on the basis of association. On such a basis this trouble could easily be placed first in importance among potato maladies. Considering the widespread prevalence of the disease and conceding even a small amount of injury it will be seen that the aggregate effect must be large.

The Plant Disease Survey Office of the U. S. Department of Agriculture has compiled estimates of losses or reductions in yield from Rhizoctonia, using the reports given by the Plant Pathologists in each state. These figures presented in the Plant Disease Bulletin (1), show that less injury is attributed to Rhizoctonia than formerly. It is undoubtedly true that, due to the failure to recognise symptoms of the virus diseases during the first part of the past ten year period, the figures for Rhizoctonia losses were higher than they should have been. The estimates for 1921-23 are more nearly correct than earlier figures and this is taking into account seasonal variations. To the loss from reduced yield must be added whatever loss is occasioned by lowered quality. The presence of sclerotia on table stock is not serious but does decrease the value of seed stock. Russet scab and tuber pits, when these appear, lower the quality of the crop even for table purposes.

It is probable that a part of the increase in loss reported for 1922 is due to increased recognition of the virus diseases. In Washington the virus diseases are considered of far more importance than the Rhizoctonia disease. The latter is influenced by climatic factors to such an extent that a true evaluation of its importance is difficult.

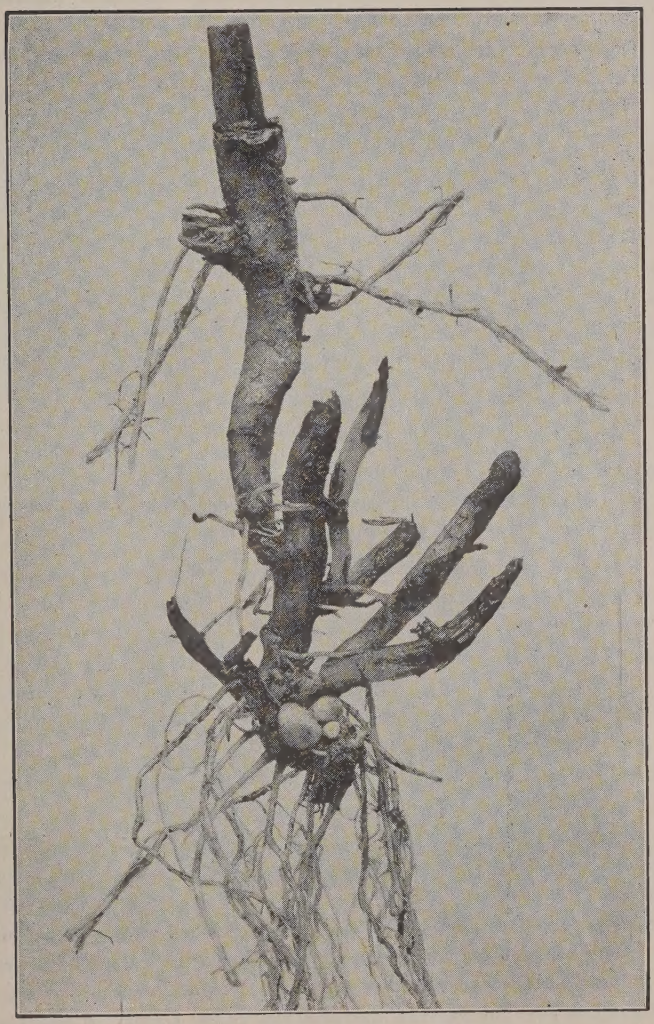

Fig. 2. Sprouts cut off by stem cankers. Note the number of unsuccessful attempts by the plant to reach the surface.

However, in point of loss it is second only to the virus diseases. The losses that are increased in crops following potatoes must also be considered. Altogether the importance of Rhizoctonia justifies additional investigational work of an extensive nature.

NATURE OF INJURY BY RHIZOCTONIA

The injury caused by the Rhizoctonia disease includes results of direct attack on the underground part of the potato plant and certain indirect effects on the top. Besides he impairment of the functions of the growing plant, the disease also affects the quality of the tubers. A matter of further interest especailly to the gardener with limited space is the fouling of the ground so that other vegetables may not be grown successfully.

Injury to the Plant Below Ground

Nearly all of the manifestations of the disease described in a popular paper on the Rhizoctonia disease of potatoes (16) are more or less prevalent in Washington State. Observations and experimental studies of these symptoms are given below.

Cankers and girdling of young stems. This phase of the disease (Figures 2 and 3) is common in very early plantings and may nearly always be found on volunteer plants. The cankers on young stems precede the severe corroding of the base of the stem (Fig. 6) in fully developed plants. This type of injury has been described by Selby (63) and the causal relationship of **Rhizoctonia solani** to it established by Drayton (19) and Edson and Shapovalov (21). Richards (58) in his temperature studies has given the explanation of its occurrence in early planted or volunteer stock.

Corroded Stems. The underground portion of the main stem becomes corroded when conditions are favorable for the continued activity of the fungus during the growth of the plant (Fig. 6). Severely corroded stems are especially common under irrigation or where there is an abundance of moisture. As noted by Orton (51) temperature and moisture both enter into the complex of conditions that favor the severe type of injury to the stems. A severely affected specimen is shown in Figure 2. Root and stolon develop-

ment have both been disturbed. The relation of corroded stems to certain top symptoms will be presented under the discussion of those symptoms.

Fig. 3. Sprouts cut off by stem cankers. Note that some eyes will not produce more shoots.

Little potatoes. The blighting of stolons brought about by the corroding of the stem just described stimulates the plant to form

stolons from the healthy portion above the corroded area, thus throwing any tubers formed near the surface of the ground. Moisture, aeration, and temperature conditions at this point are such

Fig. 4. Little potatoes from one Rhizoctonia diseased plant. (Photo by Heald)

that small, ill-shaped tubers, sometimes in considerable numbers, are clustered about the base of the stem. (Fig. 4) This type of

injury has been observed repeatedly in experimental plots and always with severely corroded stems. Little potatoes are a symptom of "witches' broom" as described by Hungerford and Dana (32) but other symptoms will serve to differentiate the two troubles.

Root blight. Impoverished root development accompanies the severely corroded stems. The development of the main roots is largely prevented or they die during the progress of the disease. (Fig. 6). Elaborated food material is prevented from passing to the root system in the usual amount and manner because of the injury to the cortex of the main stem. Impoverishment of the root system results in reduced or otherwise abnormal top development. Where plants injured in this way are abundantly supplied with moisture, aerial tubers are formed in greater numbers. Affected plants under more severe conditions usually produce a few irregular tubers near the surface of the ground. Blighting of the larger roots along with other forms of injury increases in amount roughly in proportion to the abundance of the parasite in the soil.

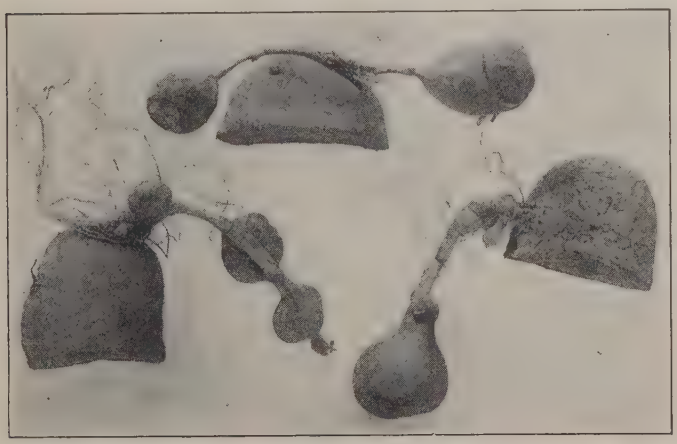

Fig. 5. Tubers produced directly from seed piece. (Photo by Heald)

Tubers but no tops. Under moist, cool conditions, the Rhizoctonia fungus is capable of destroying the shoots from the seed piece

as they appear. Continued destruction of the growing shoots will exhaust the food supply in the set or cause it to produce small tubers directly from the seed piece (Fig. 5). This phenomenom has been ascribed to the action of the Rhizoctonia fungus by Heald (30). The formation of tubers without tops may also occur under conditions where the seed tubers have become exhausted by sprout production. Wellensiek (76) found that such tuber formation may take place if tubers which had produced several crops of sprouts were planted in cold soil. He notes also that premature tuber formation may take place under conditions leading to early ripening of the tubers with more favorable conditions for growth following and that the new tubers are formed from food materials stored in the first formed tubers. This condition has also been described by Nebolsin (50). It is common in occasional years in eastern Washington.

Cook and Lint (12) think Rhizoctonia responsible for poor germination, poor stands, and occasional complete loss of crop in New Jersey. To test the effect of Rhizoctonia on germination a planting was made at Pullman in 1916 using seed of the Burbank variety heavily infested with sclerotia. Only three and one-half per cent of the tubers failed to germinate, but the cause was not definitely determined and may not have been due to Rhizoctonia. The Corticium stage of the parasite was found on forty-two and one-half per cent of the plants in this plot on the third of July. The results of this test indicate that Rhizoctonia may be prevalent and not lower germination of seed pieces greatly. It is entirely probable that Rhizoctonia does not directly cause the production of tubers without development of tops but that it may contribute to the conditions that bring about such development.

Death of feeding roots. Extensive killing of feeding roots of plants that may or may not show lesions or other visible injury, is prevalent under Washington conditions. Investigations by Matsumoto (43) show that the young roots are the most vulnerable part of the potato plant. Gussow (27) finds that death of feeding roots is common and that symptoms manifested on the top can be explained on the basis of injury to this portion of the root system. Studies in Washington show that such injury is not confined to the

Fig. 6. Badly corroded stem and aerial tubers.

potato but was found in severe form on the tomato and other plants attacked by the parasite. This type of injury is most serious in dry soils where conditions are not favorable for the plant to put out new feeding roots to take the place of those destroyed. This is one of the most serious forms of Rhizoctonia and plays an important part with the other injuries mentioned above in the production of all the symptoms appearing on the top. Severely corroded stems have been observed on apparently healthy plants but feeding root injury always produces some indirect effect on the top.

Tuber pits. The production of tuber pits has been credited to the action of Rhizoctonia by George (24), Morse and Shapovalov (48), and also by Ramsay (57). This has been disputed by Taubenhaus (71) who considers the Rhizoctonia secondary. Tuber pits have been observed during the course of these studies only in fields showing Rhizoctonia in severe amount and in prevalence somewhat in proportion to other types of injury by Rhizoctonia. The pits

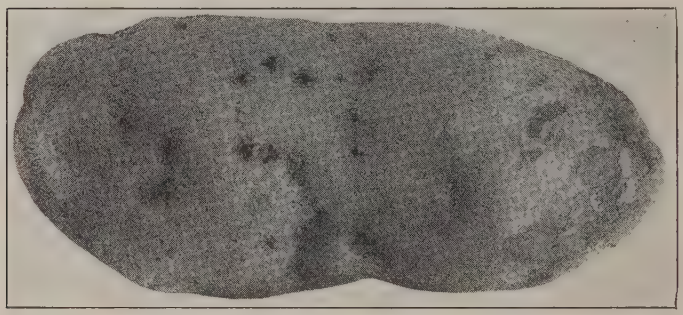

Fig. 7. Tuber pits.

which may be very narrow or may be large, irregular cavities in the flesh of the tuber as much as half an inch across are infected with mycelium of Rhizoctonia which appears to be growing in the tissue lining the pits (Fig. 7). Shapovalov has demonstrated in his work on a tuber-rot caused by Rhizoctonia, that the fungus is capable of breaking down the tuber tissue. The best evidence that can be added to that already accumulated concerning the causal relation

of Rhizoctonia to tuber pits is the occurrence of pits only in cases where plants have been severely attacked by the fungus and in greater abundance where russet scab and other forms of tuber injury appeared. Whatever may be the role of Rhizoctonia in the production of these cavities it clearly aids in their enlargement.

Tuber rot. Rotting of tubers occurs to a very limited extent in Washington. Elongated tubers from irrigated fields in the Yakima Valley have furnished specimens of this trouble. The slow rot develops at the stem end before harvest and after being placed in storage it dries down into a firm layer of dead tissue. This layer of cells is filled with Rhizoctonia fungus and the parasite has been isolated by cultures from the portion bordering the sound tissue. This rot seems to be identical with that described by Shapovalov (62) who found it on tubers with long pointed stem ends of the Burbank and Netted Gem varieties from Idaho and California.

Russet scab. Russet scab or Rhizoctonia scab is a form of injury to the surface of the tuber, a severe form of which in appearance is not greatly unlike common scab, **Actinomyces chromogenus** Gasp. This roughening of the skin may be localized or spread over the entire tuber and varies from a slight roughening to very pronounced effects. (Figs. 9 and 10). Small sclerotia are usually abundant in the cracks of the skin and mycelium is easily found by microscopic examination and even with a hand lens or the unaided eye on white skinned varieties. Russet scab is common in severely diseased fields particularly if the soil is heavy and poorly drained. It has not been observed on disease free fields and when it is found it is somewhat in proportion to the severity of other forms of the disease present. This is the best proof that can be found that Rhizoctonia really holds a causal relationship to "russet scab". It has been recognized by Darnell-Smith (17) and McAlpine (42) who note its occurrence in Australia. It was later described by George (24) who first noted its occurrence in Washington. Doidge (18) records its presence in South Africa and Paddock (53) records its ocurrence in Colorado.

Sclerotia. These bodies on the tubers (Figs. 10, 11 and 12) are extremely common in the commercial stocks grown in Washington. They may also be found on stems (Fig.9). Unfortunately the

Fig. 8. Russet scab in mild form.

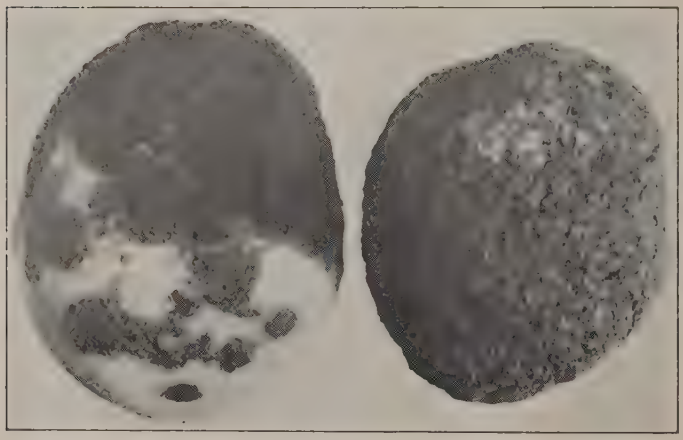

Fig. 9. Russet scab in severe form.

Fig. 10. Sclerotia of usual size on stem, stolon, roots and tuber.

prevalence of the fungus in the soil makes it difficult to raise seed stock free from sclerotia. A special feature in rather dry soils is the copious production of sclerotia on the under surface of the tuber as it lies in the soil with none on the upper surface. Growers in Washington have repeatedly reported that sclerotia are more abundant on tubers dug late in the season. This is in accord with the findings of Bisby and co-workers (7) in seed treatment tests in Manitoba. This fact needs to be taken into consideration in the

Fig. 11. Grant sclerotia naturally developed in the field about actual size.

interpretation of results extending over a number of years. It would tend to vitiate the comparison of results of plots that were not all dug at the same time. This behavior of sclerotial formation is a factor in the growing of seed potatoes for certification. However, the presence of a limited number of Rhizoctonia sclerotia on seed stock

is perhaps of less importance than freedom from virus diseases. Sclerotia can be rendered innocuous by seed treatment and are not objectionable in table stock as judged by the fact that buyers pay little attention to them in selecting potatoes on the market. The presence of sclerotia does not in any way affect the vitality or keeping quality of the tuber.

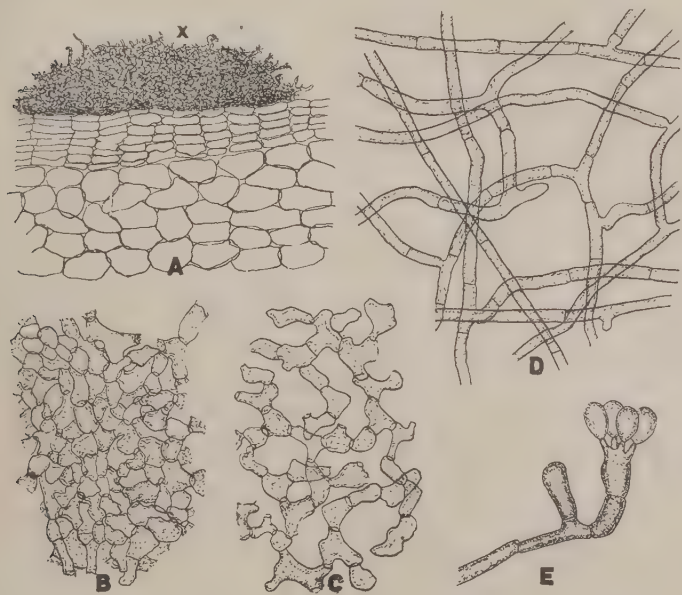

Fig. 12. Structure of a sclerotium.

Irregular tubers. Irregularity of tubers may be said to be increased by the action of the Rhizoctonia parasite. Many experiments have been conducted in the results of which no correlation could be found between the seriousness or abundance of the disease and the percentage of irregular tubers in the crop. Other experiments have shown an increase of irregular tubers roughly proportional to the amount of disease present. Conditions of temperature and moisture as factors in the production of irregular tubers far outweigh the Rhizoctonia factor partly, perhaps, because it operates indirectly.

Table 1

Correlation of the Amount of Disease with the Yield of Irregular Tubers in the Crop

Plot No.	Per cent tubers with sclerotia	Yield in lbs. of tubers		Per cent of total yield irregular
		Irregular	Total	
1	47	193	1960	8.9
2	24	101	2078	4.6
3	18	5	46	9.8
4	95	9	44	17.0

The results of one experiment are given above in which a correlation was shown between the amount of disease and the production of irregular tubers. The data brought together in Table 1 were collected in two different years. Plot 1 is comparable with plot 2 and 3 with 4. Presumably the factors other than Rhizoctonia which influence irregularity are operative equally in each pair of plots. The Netted Gem variety was used in each case. The percentage of irregular tubers is almost directly proportional to the percentage of disease in the harvested crop. This would indicate a definite relation which might be hidden because of other factors that influence irregularity of tubers.

Top Symptoms Due to Rhizoctonia

Leaf-roll. A characteristic leaf roll may be credited to the attack of Rhizoctonia on the underground portion of the plant. The rolling occurs in the young leaves at the top of the plant and is in appearance very similar to symptoms associated with water shortage. Gussow (27) and Drayton (19) maintain that the attack of the fungus on the feeding roots is responsible for rolling of leaves. The fact that the injury to feeding roots would cause water and food shortage gives support to their contention. The action of the fungus on the roots would increase the harmful effects of unfavorable growing conditions.

Some difficulty is experienced in differentiating between Rhizoctonia leaf-roll and the true leaf-roll (a virus disease). True leaf-roll may involve the upper leaves but the leaflets are more rigid and less apt to be reddish than in the case of Rhizoctonia. Similarity

in the rolling of upper leaves has been noted by Appel (2). It will sometimes require the development of progeny on sterilized soil or soil freed from Rhizoctonia to determine whether leaf-roll or simply Rhizoctonia is responsible for symptoms in a given strain of potatoes. Also true leaf-roll is heritable through the tubers and affects the lower leaves as the disease progresses which serves to differentiate the two diseases if the potato stock can be kept under observation for some time.

To gather further data on Rhizoctonia leaf-roll plants were grown on sterilized soil. Seed for this test was selected from plants showing rolling in upper leaves and also from plants more clearly affected with true leaf-roll. This work covered three years in the field and greenhouse. The study included selections from Netted Gem, Idaho Rural, Burbank, Bliss Triumph, and Irish cobbler varieties. A small amount of the leaf-roll in the top of the plant was found to be due to Rhizoctonia but the greater proportion of the progeny of the selected plants developed true leaf-roll. Even after considerable experience it was found that leaf-roll in early stages and Rhizoctonia leaf-roll cannot always be easily or certainly differentiated.

Aerial tubers. Aerial tubers (Fg. 6) have been observed in particular abundance in irrigated fields or where diseased plants were well supplied with moisture. They are also found to be a symptom of more than one disease and have been artificially produced in Rhizoctonia-free plants by Corsaut (15). Aerial tubers are known to occur in connection with black leg, **Bacillus atrosepticus** van Hall and have been found to occur with Witches' broom disease by Hungerford and Dana (32). Gussow has claimed (27) that injury to feeding roots is sufficient cause for the formation of aerial tubers. No experimental data is available on this point. However, observations show that the occurrence of aerial tubers caused by Rhizoctonia has invariably been on plants with severely corroded stems as illustrated in Fig. 2. In every case conditions favoring the severe stem injury have also favored aerial tubers.

The aerial tubers may attain a length of three to four inches and a diameter of as much as two inches. The larger specimens are produced low on the plant. The tubers bear leafy shoots sometimes

as much as an inch or two in length from the eyes. The longer shoot develops from the bud end of the tuber. Where moisture is abundant and severe stem and root injury occur aerial tubers may be formed in practically every leaf-axil on the plant and may weigh in the aggregate more than those produced underground. While aerial tubers may be formed in response to more than one factor, their development in Washington fields is in the majority of cases due to Rhizoctonia attack.

Yellowing of plants. Yellowing in large and fully developed plants has been investigated by the study of the progeny of such plants found growing in rather dry situations which were also severely affected with stem injury or feeding root injury. Progeny of these selections grown in sterilized soil were found to be free from virus diseases. This is rather conclusive proof that Rhizoctonia injury is responsible for a yellowing of large plants.

The collar fungus. This development of the Rhizoctonia (Fig. 13) has been described by Rolfs (60). In a moist atmosphere a whitish layer of mycelium develops about the stem just above the ground level and also on other parts of the plant in contact with moist soil. In the non-irrigated parts of Washington the "collar fungus" develops only during or just following rainy periods. Under irrigation there is sufficient moisture so that this stage may be found at any time. The collar fungus develops from the mycelium below ground and its presence does not seem to injure the plant. Besides being the spore stage of the parasite, it indicates severe infestation of the soil with an active and virulent strain of Rhizoctonia. Where the "collar fungus" has been abundant, susceptible crops following potatoes are usually severely injured and some crops less susceptible are advisable for the rotation.

Symptoms With Doubtful Relation to Rhizoctonia

Rosette. Rosette was assigned by Selby (63 and 64) to the action of Rhizoctonia, who fortunately gave very full descriptions and observations. His data analysed on the basis of present knowledge of the virus diseases is not sufficient to prove the causal relationship of Rhizoctonia to rosette. Since the publication of Selby's

work, numerous writers have given rosette as a symptom of Rhizoctonia. It must be admitted that rosette is very commonly associated wih severe Rhizoctonia injury to root and stem, but association in this case is not sufficient proof of causal relationship as is seen in the following instance.

Fig. 13. Collar fungus or Corticium stage of the parasite (after Heald).

In a field of volunteer potatoes growing at Pullman it was found that every plant in the field showed severely corroded stems and injured root systems. Plants were found in the field showing typical leaf-roll, rosette, witches' broom, rugose mosaic, and other plants were noted with combinations of these diseases. Still other plants equally injured by Rhizoctonia showed normal top development. A study was made of the progeny of plants showing rosette and other symptom complexes under conditions where Rhizoctonia was eliminated. On the basis of this work it can be certainly stated that rosette as it occurs in Washington is a complex resulting from virus disease infection. This is in agreement with the findings of Orton (51) who does not mention rosette or abnormally large plants as symptoms of Rhizoctonia.

Large tops. Large tops with few or no tubers were described by Paddock (53) as due to Rhizoctonia. There is a reference to this symptom in a discussion of potato failures by Rolfs (59) who also credits it to Rhizoctonia attack. Among others Carpenter (10) has mentioned the same symptom for Rhizoctonia. A somewhat similar symptom has been described from Colorado by Fitch (22). In this case an abnormally large plant was accompanied by a peculiar shape and size of tuber. A trouble with abnormally large vine development has been described by Folsom (23) and the name Giant Hill used to designate the trouble. Giant Hill has also been recognised by Gilbert (25) and has been observed repeatedly in many different varieties grown in Washington. In many cases such symptoms were accompanied by Rhizoctonia injury to the root system. Such vine symptoms have been found to be tuber transmitted by Folsom (23). Studies at the Washington Station have progressed far enough to make certain that Rhizoctonia plays no part in the production of Giant Hill symptoms and to cast doubt on the relation of Rhizoctonia to large top development of any kind. Association of Rhizoctonia with these symptoms appears to be by chance and is certainly not constant.

Rhizoctonia on Crops Following Potatoes

Soil infection. The fouling of the ground through a diseased crop or continued cropping to potatoes was mentioned above as of

special concern to the grower with a restricted area. The small garden plot on the city lot seems most often to be the scene of disappointment because of severely infested soil. In addition to pronounced failures many such gardens are unproductive due to root injury which is not severe enough to attract attention. Therefore, more should be charged to the account of Rhizoctonia than the distinct failures which are to be definitely diagnosed. No other crop is as effective as potatoes in filling the soil with a virulent strain of Rhizoctonia. Perhaps no other crop is as frequently found in the home garden as potatoes. In addition, susceptible crops very often follow potatoes in restricted areas thus adding to the soil infestation. A similar condition may occur in portions of larger fields but rotations there are generally less favorable for the increase of the parasite.

Crops affected. Some instances may be noted of crops following potatoes that have become badly infested with Rhizoctonia. Beans have repeatedly been failures because of soil infestation. In each case the soil had been cropped to potatoes and later growing of beans had to be abandoned because of the disease. Severe injury to spinach, peas, strawberries and tomatoes has also been observed in cases where these crops followed potatoes. Onions and carrots are seldom severely attacked by Rhizoctonia. However, severe injury to these crops by Rhizoctonia when following a crop of potatoes has been noted by Heald (31). These cases are sufficient to show that a crop of infected potatoes is a menace to following crops.

CONTROL OF THE RHIZOCTONIA DISEASE

Studies on control of this disease have engaged the larger part of the resources applied to the study of the Rhizoctonia problem. A considerable mass of data has been accumulated during the ten year period covered by the investigations. This will be correlated in so far as possible with data published by other workers.

Climatic conditions, locations of experimental plots, seed stocks, and methods employed in the experimental work are all important in the interpretation of results obtained and will be briefly discussed before the presentation of experimental data.

Conditions of the Experiments

Climatic conditions. The bulk of the field work has been done on the Experiment Station Farm at Pullman. The rainfall over this

Table 2

Precipitation at Pullman, 1913-1924

	Apr.	May	June	July	Aug.	Sept.	Total
1913	1.50	1.60	2.81	0.07	0.26	0.94	23.57
1914	1.29	1.21	1.26	0.13	0.00	1.20	16.61
1915	1.59	2.77	0.53	0.77	0.00	0.63	19.24
1916	1.02	1.56	2.34	0.45	1.24	0.68	26.52
1917	4.21	2.25	0.56	0.00	0.00	0.84	23.01
1918	.46	0.75	0.57	0.85	0.68	0.73	15.67
1919	1.84	1.03	0.30	0.04	0.14	0.49	18.30
1920	2.96	0.95	1.56	0.70	0.92	2.00	21.12
1921	2.34	1.86	0.87	0.05	0.15	1.53	21.53
1922	1.42	0.22	0.08	0.00	1.49	0.52	15.39
1923	1.22	1.02	3.01	0.69	1.20	0.17	18.48
1924	0.24	0.00	0.57	0.55	1.56	0.78	12.84.

period has varied from 12.84 inches to as high as 26.52 inches for the entire year. Rainfall and temperature data given here are from the official records of the Department of Soils, Washington Agricultural Experiment Station.

The precipitation for the growing period as well as the total for the year is given in Table 2. The moisture supply has unquestionably been the limiting factor in production and many of the plot yields are small because of scarcity of moisture. This, however, is not true of plots grown in 1916 when a yield of eight tons per acre was secured on land cropped every year. Temperatures for 1916 were subnormal and therefore more favorable for the parasitism of the fungus as demonstrated by Richards (58). The temperature records for the growing season 1913-24 are given in Table 3. The spread between day and night temperatures is relatively large and comparatively low temperatures prevail at the beginning and close of the growing period.

Table 3

Air Temperatures at Pullman, 1913-24

		1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
Apr.	Mean max.	54.6	56.8	60.0	53.4	47.2	56.7	56.6	48.7	52.2	49.9	56.2	54.8
	Mean min.	36.2	38.0	40.5	37.8	34.2	36.5	37.7	34.2	32.4	33.3	37.8	35.6
	Mo. mean	45.4	47.4	50.2	45.6	40.7	46.6	47.1	41.4	42.3	41.6	47.0	58.1
May	Mean max.	62.3	68.7	61.8	56.6	60.5	61.2	61.6	59.3	65.8	63.5	63.0	73.9
	Mean min.	42.4	44.7	44.7	38.7	42.1	40.3	40.9	40.0	42.8	42.0	44.0	46.6
	Mo. mean	52.3	56.7	53.2	47.6	51.3	50.7	51.2	49.6	54.3	53.7	53.5	60.2
June	Mean max.	73.9	70.1	70.7	67.0	70.5	78.3	73.9	68.2	72.4	80.8	66.5	74.4
	Mean min.	53.7	48.8	47.5	46.2	46.4	47.7	42.6	45.4	52.0	54.2	47.2	49.7
	Mo. mean	63.8	59.4	59.1	56.6	58.4	58.0	58.2	56.8	62.2	67.5	56.8	62.0
July	Mean max.	83.9	88.2	79.0	74.2	85.4	81.6	79.5	82.9	81.5	85.0	81.3	81.8
	Mean min.	57.6	58.4	53.7	52.8	56.9	56.3	53.5	54.9	50.8	57.0	55.3	53.6
	Mo. mean	70.7	73.3	66.3	68.5	71.1	68.9	66.5	73.9	66.1	71.0	68.3	67.7
Aug.	Mean max.	85.3	76.2	94.7	80.1	85.6	76.0	82.7	82.1	82.1	83.0	83.0	81.2
	Mean min.	58.4	54.1	61.1	52.7	56.9	54.1	52.2	53.8	54.4	57.6	51.5	53.6
	Mo. mean	71.8	65.1	77.9	66.4	71.2	65.0	67.4	67.9	68.2	70.3	67.2	67.4
Sept.	Mean max.	75.4	64.3	70.2	70.2	74.6	79.4	71.2	69.8	60.0	74.7	58.4	65.2
	Mean min.	47.9	44.0	47.1	45.0	50.2	53.0	44.1	47.6	41.4	49.2	48.2	42.6
	Mo. mean	61.1	54.1	58.6	57.6	62.4	66.2	57.6	58.7	50.7	61.9	53.3	53.9

Precipitation at Prosser and at Yakima where some of the experiments were carried out is negligible and the potatoes are grown under irrigation. The plots at Yakima received plenty of water but those at Prosser really suffered because of shortage of moisture during the first part of the growing season. The results secured at Yakima and Prosser are important as a large part of the potato crop of Washington state is grown under irrigation. Production under dry land conditions is increasing but yields are below what has been obtained frequently in the central Washington irrigated valleys. On the whole, climatic conditions influencing the experimental plots have been rather unfavorable for the development of the potato plant although not above the critical temperature for pathogenic action of the fungus parasite.

Location of plots. The plots at Pullman were largely located on land that had previously never grown a crop of potatoes. The value of seed selection is shown more clearly on such land. The disease developing in these plots is either carried by seed stocks or the fungus is already present in the soil. In the Yakima Valley, the plots were laid out on the County Poor farm. The land had not been in potatoes for several years but the soil proved to be full of Rhizoctonia in virulent form, so that clean treated seed gave a badly diseased crop. Water for these plots was abundant and yields high and comparable with the best commercial fields.

The irrigated plots at Yakima and those at Prosser were on light, well aeriated sandy soil which when well watered furnished favorable conditions for the parasitism of Rhizoctonia. The plots at Prosser on the Irrigaton Branch Station were placed on land that was being brought under cultivation from the virgin sagebrush. A crop of alfalfa had been grown on the land just previous to the potato crop. Yields were somewhat reduced because of moisture shortage and the light moderately rich soil.

Seed stocks. The Netted Gem variety has been used extensively in these experiments. It is the standard, main crop potato for the greater portion of the state. In addition, some work was done using the Gold Coin, and Burbank varieties. Observations on the attack of Rhizoctonia on these and other varieties grown in the state have shown no noticeable variation in variety susceptibility.

Selection of seed stocks was made in every case from the bin to obtain stock with sclerotia on a portion of the tubers. In each case a fair yielding strain was secured with no more of the virus disease than is to be found in average market seed stocks. Results, therefore, are such as are to be secured on the majority of farms where potatoes are grown in the State.. The virus diseases were uniform in seriousness throughout a series of experiments so that they may be ignored in the interpretation of results as they may be considered to be evenly distributed and seemingly do not affect the parasitism of Rhizoctonia. Seed stocks free from these diseases would have been desirable if such could have been found which were also affected with a considerable amount of Rhizoctonia, but such stocks were not available and it is thought that perfectly valid results have been obtained with the seed stocks used.

Cultural methods. In the preparation of seed for experiments comparing clean and infected seed an attempt was made merely to separate a given lot into stock that was carrying visible sclerotia and that not having sclerotia as far as could be determined by naked eye examinations. Undoubtedly mycelium could have been found on the clean seed by microscopic methods. Nothing artificial was introduced but a division or selection made such as is easily possible on any farm.

Treatment, except in certain of the seed treatment experiments, was carried out according to the sandard mercuric chloride method previously described in a popular paper (16) and in common use wherever seed treatment is practiced. Treatment has been introduced into enough of the experiments so that conclusive evidence may be presented as to its value to the home gardener, the commercial grower and the grower of certified seed.

Cultivation of the plots at Pullman was carried out to conserve moisture and keep weeds under control. In every case the plots had raised some kind of crop the year previous. The plots grown under irrigation were handled in the usual manner for those regions excepting that at Prosser the water supply was not sufficient for the first part of the growing season to promote the best growth of the plants. Control of the Colorado beetle was unnecessary excepting in the case of an occasional plant in some years.

Harvesting was done after the plants had become mature in the case of most of the experiments. It was done in every instance by hand and careful records kept to acertain the total yield and yield of marketable tubers. Unmarketable stock was divided and records kept of small stock and irregular tubers to determine the influence of the disease on the quality of the crop. Inspection of the marketable portion of the crop was made in each case to find the percentage of tubers that carried sclerotia. Work by Bisby, Higham and Groh (7) has shown that the number of sclerotia is influenced by the date of digging. In work reported here all of an experimental plot was dug at one time so that results are comparable for the experiment although results for different years may not be strictly comparable. Observations were made during the growing season for uniformity of plot and presence of diseases other than Rhizoctonia together with the amount and effects of the Rhizoctonia infection as shown by top characters.

Seed Selection Studies

Selection of seed free from sclerotia is possible in cases where there is a sufficient quantity to choose from and more likely to be carried out where there is but a light infection in stock. Seed selection has shown results equal to seed treatment and with seed treatment enables one to secure the maximum control. Data on seed selection can be drawn from nearly all of the experimental data that are presented below. However, data have been selected that illustrate what can be expected from seed selection under dry land culture and under irrigation. The influence of soil infection will also be shown.

Influence of virus diseases. No direct relation is found between the virus diseases and susceptibtility to Rhizoctonia. As a basic principle, however, seed stocks must be reasonably free from virus diseases before satisfactory yields can be expected. With unsatisfactory yields, the benefits of seed selection, seed treatment or any cultural practices are limited. Running out of strains or varieties is due to the so-called degeneration diseases or virus troubles. It is necessary then to use a virus-free or high yielding strain of seed before results worthwhile may be expected from seed selection.

Experiments on clean soil. Seed selection studies were carried on using at different times clean soils, irrigated and non-irrigated and also contaminated soils, irrigated and non-irrigated. The results to be secured from seed selection are seen to be influenced by soil infection and possibly to some extent by irrigation Data gathered on clean soil under dry land culture will be presented first, followed by data gathered under irrigation.

1. Non-irrigated soil. The experiments using non-irrigated soils were all conducted at Pullman. The soil used was considered clean soil because so far as could be learned no crop of potatoes had been grown on the land since it was brought under cultivation from the virgin state. All this land had been farmed from 15 to 20 years.

In the 1917 experiments on non-irrigated soil, the Netted Gem and Gold Coin varieties were used. Seed of each variety was divided into two lots. Tubers visibly free from sclerotia were sorted out and designated as clean seed and the remaining tubers visibly infected with sclerotia were designated as infected seed. A portion of each lot was given the standard mercuric chloride treatment. Total yields were taken and examinations made for freedom from sclerotia. The data secured from this test are presented in Table 4.

Table 4

Comparison of Sclerotia-free and Sclerotia-bearing Seed Tubers, 1917 at Pullman

Seed stocks used			Total yield in lbs.	Per cent tubers clean
Variety	Selection	Treatment		
Netted Gem	Clean	Untreated	554	44.1
Netted Gem	Clean	Treated	344	77.5
Netted Gem	Infected	Untreated	465	1.3
Netted Gem	Infected	Treated	406	0.6
Gold Coin	Clean	Untreated	480	79.6
Gold Coin	Clean	Treated	407	82.7
Gold Coin	Infected	Untreated	469	44.1
Gold Coin	Infected	Treated	489*	59.4

*This plot contained an outside row which materially increased the yield.

Selection was more effective in controlling disease in the crop than treatment. The fact that clean treated seed produced a crop with only 77 and 82 per cent clean shows that the soil carried some of the fungus which was probably native in the soil and had persisted through the years of cultivation. Selected seed untreated has given the greatest yields.

Additional data on seed selection can be drawn from a test with the Netted Gem variety on soil treatment plots. The soil treatments had little effect but both clean and infected seed were used. These data are summarized at the bottom of Table 13. Infected seed gave a crop of infected tubers while selected seed gave a crop with an average of better than 50 per cent clean tubers. The yield of marketable tubers is greatest from clean seed and again clean untreated seed has given the highest yield of the series.

Table 5

Comparison of Sclerotia-free and Sclerotia-bearing Seed Tubers, 1918 at Pullman

Seed stocks used			Yield in lbs. of tubers		Per cent tubers clean
Variety	Selection	Treatment	Marketable	Total	
Netted Gem	Clean	Untreated	355	394	76.9
Netted Gem	Clean	Treated	453	500	89.4
Netted Gem	Infected	Untreated	494	572	10.4
Netted Gem	Infected	Treated	365	425	12.4
Gold Coin	Clean	Untreated	638	670	74.6
Gold Coin	Clean	Treated	393	416	87.7
Gold Coin	Infected	Untreated	519	567	7.0
Gold Coin	Infected	Treated	396	433	42.4
Burbank	Clean	Untreated	390	472	87.2
Burbank	Clean	Treated	313	420	95.2
Burbank	Infected	Untreated	273	331	16.6
Burbank	Infected	Treated	219	298	80.1

In the 1918 experiments on non-irrigated soil the Burbank variety was added to the Netted Gem and Gold Coin varieties for the

test of seed selection. Somewhat better control was secured by seed selection in this years work showing less soil contamination. With Gold Coin and Burbank varieties clean untreated seed gave the highest yields. Data for these plots are assembled in Table 5. The low percentage of clean tubers from infected, untreated seed shows that a heavily infected crop may result from fungus carried into the soil in the form of sclerotia. Treatment has more influence in lowering yield than in reducing infection as indicated by sclerotia on the harvested crop.

In addition to the experiment noted above which was planned to show results of selection and treatment, the data in Table 14 may be examined for influence of selection on diesease in the harvested crop. The data in this table were gathered in a test of the effects of soil treatments in which clean and infected seed was used. The summary at the end of the table shows that clean seed treated may produce a clean crop while infected seed even with treatment gives no promise of a clean crop.

In the 1919 experiments on non-irrigated soil, the soil treatment tests mentioned above were repeated and show some favorable results from seed selection. The data for this test are to be found in Table 15. An average of all plots of clean seed shows 80 per cent of clean tubers in the crop while an average of all plots of infected seed shows only 13.8 per cent clean tubers in the crop. The yield of the clean seed even with the handicap of treatment compares favorably with the yield of the infected seed. Additional data on seed selection are to be found in Table 17 where results of a spraying experiment are recorded in which clean and infected seed was used. Clean seed gave a high percentage of clean tubers while infected seed gave a very small percentage of clean tubers in the crop.

Data collected in the 1923 experiments on non-irrigated soil, are given in Tables 20 and 21. In these tables are found results of clean and infected seed planted at intervals during the first part of the growing season. Results are somewhat variable among the plantings on different dates. In general, clean seed has given a slightly cleaner crop than infected seed. Reference to the summary of data in Table 21 will show that here seed treatment was more

efficient than seed selection in lowering infection in the crop. Neither has proved as efficient factors in reducing infection as was demonstrated in the work of other years.

2. Irrigated soil. These experiments under irrigated conditions were conducted at Prosser on soil that had been in cultivation but three or four years and had raised a crop of alfalfa which was turned under for the potatoes. What Rhizoctonia there was in the soil could only be that which was indigenous or native in the virgin soil.

In the 1922 experment, planting at different dates throughout the spring was carried on using clean and infected seed. These data are collected in Table 22 and summarized in Table 23. Clean untreated seed did not give as clean a crop as clean treated seed, while clean treated seed was little better in this respect than infected treated seed. The treatment in this case was very efficient as shown in the reduction of infection in the resulting crop. The summary in Table 23 shows that selection and treatment were of about equal efficiency in the production of a clean crop. Selecton increased the yields as did also treatment, again showing about equal value in this respect. Here again the cleanest crop resulted from both seed selection and seed treatment.

In 1923, the above experiment at Prosser was repeated using clean soil and clean and infected seed. Data are given in Table 24 and summarized in Table 25. Results were very comparable to those secured in 1922. Selection and seed treatment again proved of about equal merit. Here the cleanest crop is secured with both selection and treatment. Slightly depressed yields are shown by treatment in the summarized figures at the end of Table 25.

The seed selection studies on clean soil have covered a number of years and it is fortunate that data were collected under irrigated and non-irrigated conditions. These data bear out the following statements:

1. Infected untreated seed is certain to give a crop of infected tubers unless planted so late in the season that satisfoctory yields are not assured.

2. Clean treated seed may be depended upon to give the cleanest crop that may be grown.

3. Selection in some cases is superior, in others of about equal value to seed treatment in the production of clean crops.

4. Sclerotia carried into the soil on the seed are sufficient inoculum to insure a large percentage of infection in the crop.

5. A certain amount of disease may be expected to appear as a result of Rhizoctonia indigenous in virgin and cultivated soils even though these have not become contaminated through a crop of potatoes.

Experiments on Contaminated Soil. Because of the impossibility of securing clean soil some work was done in which the plots were located on soil that was known to be infested or which proved to be contaminated from the results secured. The plots at Pullman were on land that was known to be heavily infested while the land at Yakima proved to be heavily infested although potatoes had not been grown for a number of years.

1. Non-irrigated soil. The plot used had previously been in garden crops including potatoes. The data gathered in the single experiment using infested, non-irrigated soil are given in Table 18 and summarized in Table 19. This work was carried out in 1922. Soil contamination is seen to have obliterated any effects of selection or seed treatment in producing clean crops.

2. Irrigated soil. Contaminated soil was unintentionally selected in 1918 for some work at Yakima on seed selection, seed treatment, and Bordeaux spraying. The plots were located on the county poor farm and had not raised a crop of potatoes for several years. The soil was rich and irrigation water was abundant. Two lots of seed were used: Netted Gem of ordinary market quality, divided into clean and infected lots; and a lot of clean seed that had been grown in the Yakima Valley for three years and rigidly rogued and selected during that time was secured for comparison with the ordinary seed. Yield and disease data are presented in Tables 6 and 16. The plots were one-eighteenth acre in size and all uniform as to soil, culture, etc. The data from the selection and seed treatment plots are presented in Table 6. Data bearing on seed selection may also be found in Table 16, which gives the results of both clean and infected seed used in the plots to which spray was applied. Seed

selection proved of no value in reducing the precentage of disease in the harvested crop. Clean seed in both cases produced the largest yield. The special lot of seed far outyielded the other lot and also produced a cleaner crop. The vigor of seed and consequent vigor of plants is the only explanation for the greater freedom from disease in the crop from this plot. The fungus that was already in the soil was sufficient to cause development of sclerotia on most of the new crop. It will be seen, however, that the fungus carried into the soil on the infected stock was more active and was responsible for marked reduction in yield.

Table 6

Comparison of Sclerotia-free and Sclerotia-bearing Seed Tubers, 1918 at Yakima

	Seed stocks used		Yields in lbs. of tubers		Per cent tubers clean
	Selection	Treatment	Marketable	Total	
Lot 1	Clean	Untreated	1201	1764	2.8
	Clean	Treated	1469	2165	1.4
	Infected	Untreated	697	1281	0.7
	Infected	Treated	640	966	2.1
Lot 2	Clean "selected"	Untreated	2062	2688	32.1

The following statements additional to those above are based on the seed selection work at Yakima: 1. The fungus carried on the seed is more active than that in the soil especially if no potatoes have been grown on the soil for several years. 2. Special selection of seed is justified on the basis of increased yields. 3. Selection of clean seed, in so far as it can be applied, is worthy of serious consideration by the commercial grower. 4. Both seed selection and seed treatment should be used by the seed grower, but they are of little or no value if the crop is grown on infested soil. 5. Selection and treatment will aid the gardener with restricted area in keeping his ground free from Rhizoctonia. 6. Selection is of about equal value with seed treatment in control of disease in the crop. 7. Division of seed stock into clean and infected lots would seem advisable even though both lots of seed had to be used. Infected seed could then be

more thoroughly treated or in some cases treated while the clean seed was used without treatment. 8. Fouling of the ground with Rhizoctonia is to be considered serious under irrigation, in restricted garden areas, and in seed growing areas. It is less serious in non-irrigated areas of commercial production only because potatoes are used less in the rotations and the same soil need not be used for potatoes except at long intervals.

Seed Treatment Studies

Studies on seed treatment have included tests of different fungicides that may be employed, the length of the period of treatment, the effect of the treatment on yield, and the efficiency of treatments in controlling the Rhizoctonia disease. These studies have extended through practically the whole of the past ten years and have included plots under dry land culture and under irrigation as well as on new land and areas cropped to potatoes and known to contain Rhizoctonia in virulent form.

Table 7

Comparative Efficiency of Formaldehyde and Mercuric Chloride Treatments for Rhizoctonia

Treatment of infected seed	Yield in lbs of tubers		Per cent tubers sclerotia-free
	Marketable		
None	250	314	49.6
Formaldehyde 1 lb. .to 30 gal. water	232	278	73.1
Mercuric Chloride 4 oz. to 30 gal. water	185	220	83.5

Comparison of formaldehyde and mercuric chloride. One test was made in 1916 to verify the findings of other workers. A stock of heavily infected tubers of the Burbank variety was secured and divided into three lots. One lot was given no treatment. One lot was treated for two hours in a solution of formaldehyde made up by using one pound of commercial formaldehyde (37-40%) in thirty gallons of water. The third lot was treated for two hours in mercuric chloride made up by using four ounces of the chemical in thirty gallons of water. The three lots were planted on land that had been in a berry plantation for several years. The season of 1916 was one

of subnormal temperatures and for that reason favorable for the development of the disease. Results of this test are given in Table 7.

Formaldehyde gave an increase of clean tubers over the check plot but caused a small reduction in yield of marketable tubers and also reduced the total yield. Mercuric Chloride gave a still larger percentage of clean tubers and also caused a greater reduction in yield. Our results in the control of Rhizoctonia are in agreement with those secured by Coons (13) in Wisconsin, Cook and Lint (12) in New Jersey, Gussow (28) in Canada, Gloyer (26) in New York and Melhus, Gilman and Kendrick (46) in Iowa. The work of these investigators is so generally accepted that no further discussion of our results is necessary.

Comparison of mercuric chloride and copper carbonate. The extensive use of copper carbonate for controlling cereal diseases led to a test in a small way of the efficiency of copper carbonate for Rhizoctonia control. The first test was carried out in 1922 at Pullman using Sclerotia-bearing tubers of Netted Gem variety, planted on land that had previously been in potatoes. Four lots of seed were used.

1. No treatment.
2. Copper carbonate dust applied to dry tubers before cutting at rate of 24 grams per bushel.
3. Copper carbonate dust applied to tubers immediately after cutting at rate of 60 grams per bushel.
4. Copper carbonate dust applied to wet tubers before cutting at rate of 60 grams per bushel.

The method used was to dust the seed and calculate the amount of the chemical that adhered to the seed at the time of treatment. The four lots were planted the day treated and all were dug on the same day. The results were erratic as shown in Table 8. No effect was noted in this test on yield and the number of sclerotia in the crop was apparently not greatly influenced by the treatment. The soil was known to be infested with Rhizoctonia and this undoubtedly accounted for the erratic results. The copper carbonate certainly did not have any value as a protection against infection from Rhizoctonia already in the soil.

The use of copper carbonate was again tested in 1923 with plots on soil that had not previously raised a crop of potatoes. Three lots of infected seed were used: (1) Not treated, (2) Dusted with copper carbonate at rate of twenty grams per bushel after cutting. (3) Dusted with copper carbonate at rate of twenty grams per bushel applied to moist tubers before cutting.

Table 8

Copper Carbonate Treatment for Rhizoctonia in 1922

Seed treatment	Yield in lbs. of tubers		Per cent tubers sclerotia-free
	Marketable	Total	
None	45	80	4.6
Copper carbonate dust to dry tubers before cutting	37	77	23.4
Copper carbonate dust to freshly cut tubers	35	63	6.8
Copper carbonate dust to moist tubers before cutting	50	81	2.5

Table 9

Copper Carbonate Treatment for Rhizoctonia in 1923

Seed treatment	Yield in lbs of tubers		Per cent tubers sclerotia-free
	Marketable	Total	
None	166	203	66.9
Copper carbonate dust after cutting	30	52	80.4
Copper carbonate dust to moist tubers before cutting	149	196	47.9
Mercuric chloride 18 days before cutting	184	203	91.6

The Netted Gem variety was again used and on plots located at Pullman less satisfactory results were secured than in the test conducted in 1922. Results are recorded in Table 9. The three lots were planted the day following treatment and all were dug on the same day so that they should be comparable. Of particular interest was the effect of copper carbonate after cutting. There was about a fifty per cent stand in this plot compared with practically a

perfect stand in the other plots. The original seed lot was the same and the planting and other operations carried out in the same manner so that reductions in yield must be credited to the action of the copper carbonate. There was no satisfactory reduction in disease and the yield because of poor stand was unsatisfactory. The fourth lot of seed treated with mercuric chloride was the same as the other three and planted at the same time so as to be comparable with the three other lots.

Further tests with copper carbonate were discontinued because of the unsatisfactory results secured in 1922 and again in 1923. Laboratory tests have not been carried out to determine the basis for interpreting the field data.

Table 10

Comparison of Corona Compound 620 and Mercuric Chloride Treatment for Rhizoctonia in 1923

Seed treatment	Yield in lbs. of tubers		Per cent tubers sclerotia-free
	Marketable	Total	
None	166	203	67.0
Corona Compound 620	293	416	67.6
Mercuric chloride	184	204	91.7

Comparison of "Corona Compound 620" and mercuric chloride. A single test with Corona Compound 620 was carried out. The same seed stock was used in the test with copper carbonate and the plots planted at the same time so that a direct comparison may be made. Table 10 gives a comparison of this organic mercury compound with mercuric chloride and with untreated seed. The Corona Compound and mercuric chloride were each used at the rate of four ounces to thirty gallons of water and the seed treated for two hours. The treatment was caried out two weeks before planting, using seed that had been kept moist 12 to 24 hours before dipping into the treating solution. No explanation is apparant for the increased yield over the other plots. It is unfortunate that additional tests have not been made to determine the effect of this treatment on yield. These tests although somewhat meager do not offer anything superior to the

standard mercuric chloride treatent. Additional work on the mercuric chloride treatment will be recorded under the following heading.

Variation of the mercuric chloride treatment. The effect of varying the strength of the treating solution and the time of treatment was tested in 1918 and repeated again in 1919. Infected seed of the Netted Gem variety was used and the following treatments given where the seed was soaked in a solution of mercuric chloride:

4 oz. to 30 gal.
6 oz. to 30 gal. } for ¼, ½, 1, 1½ and 2 hours.
8 oz. to 30 gal.

Table 11

Variation in Strength of Solution and Duration of Mercuric Chloride Treatment for Rhizoctonia at Pullman in 1918

Plot No.	Treatment		Yield in lbs. of tubers		Per cent tubers sclerotia-free
	Oz. to 30 gal.	Duration (hrs.)	Marketable	Total	
1	4	2	121	167	64.3
2	6	2	187	218	86.3
7	4	1	141	171	26.8
8	6	1	168	222	81.8
9	8	1	99	137	76.6
10	4	½	129	191	16.7
11	6	½	79	119	32.8
12	8	½	79	112	57.7
15	8	¼	111	139	19.1

The plots were located on clean land and handled alike so as to secure comparable results. The data in Table 11 are incomplete because of accident to six of the plots. The data in Table 12 include two check plots planted with the orignial infected untreated seed.

Several points are borne out by the data in these two tests: 1. The longer treatments are more reliable than the shorter treatents. 2. Reduction in yield may be expected from treatment with the stronger solutions for the two hour period. 3. Increased yield

is secured from treatment with the stronger solutions for the shorter periods of time. This is more noticeable for the 1, ½ and ¼ hour treatments as compared with the four ounce solution. 4. The fungicidal action of the chemical is operative at the shortened periods of treatment without the injury to the potato tuber noticeable in the two hour treatments. 5. A one fourth hour treatment increased the percentage of clean tubers in the crop over the untreated stock.

Table 12

Variation in Strength of Solution and Duration of Mercuric Chloride Treatment for Rhizoctonia at Pullman in 1919

Plot No.	Treatment		Yield in lbs. of tubers		Per cent tubers sclerotia-free
	Oz. to 30 gal.	Duration (hrs.)	Marketable	Total	
1	4	2	84	99	22.5
2	6	2	77	91	98.5
3	8	2	62	83	33.3
4	4	1½	53	70	0.8
5	6	1½	51	69	17.2
6	8	1½	74	99	68.4
7	4	1	84	113	5.1
8	6	1	52	67	77.6
9	8	1	102	129	63.9
10	4	½	64	82	23.4
11	6	½	90	119	24.1
12	8	½	106	113	54.4
13	4	¼	40	57	18.3
14	6	¼	69	109	19.6
15	8	¼	91	108	43.1
16	No treatment		87	138	2.1
17	No treatment		101	150	6.5

It is unfortunate that a laboratory study of these lots of seed was not made to secure data that would have been comparable with the data of Thurston (73) and Melhus and Gilman (45). Our results do not show as good control with corrosive sublimate, 4 ounces to

thirty gallons of water, as was secured by Coons (13, 14) and by Kotila (34). On the basis of these results treatment periods of less than one hour are unsatisfactory and much better results may be expected with the two hour treatments unless double the ordinary strength of solution is used.

Mercuric chloride treatment and yield. The influence of this treatment on yield is a question of practical importance. Workers elsewhere have claimed substantially increased yields from corrosive sublimate treatment. Some of these results may be noted and compared with data gathered in Washington. Chupp (11) reports a gain in yield from seed treatment of 14-48 bushels per acre with a five year average of 26 bushels. Stakman and Tolaas (67) found that seed selection and seed treatment increased the yield in 16 fields an average of 5-6 bushel per acre. Selvig (60) found results from seed treatment variable but justified in increased yields and a cleaner product. Quanjer (56) reports increased yields of marketable tubers on infested and non-infested soils in Holland. Stokdyk (70) reports an increase of 14-130 bushels with an average of 41 bushels for 22 tests. Kotila (34) reports increased yields from treatment in Michigan.

The workers mentioned have collected data in widely separated areas and of necessity under widely varying climatic conditions. Their findnigs are conclusive enough to justify the general recommendation of seed treatment as a practice for commercial growers as well as for the seed grower who should always employ seed treatment even in the face of some reduction in yield. The practice of seed treatment in many regions would seem justifiable on the basis of yield alone.

Results less satisfactory have also been noted in the literature. Appel (2) found seed treatment of little value in severely infested soils. Investigators in North Dakota (47) also found seed treatment of no value because of soil infestation even though potatoes had not been grown on the area for some years. Jones (33) working in Vermont found that corrosive sublimate treatment just before planting retarded the germination of the sets and the growth of the plants. No retarding efect was noticed when the treatment was given 1½-3

months before planting. In no case was there a gain in yield from treatment that was large enough to be of any consequence. Thompson (72) working at the Duluth Substation in Minnesota also reports reduced yields from corrosive sublimate treatment. These reports, indicate a possible unfavorable effect of corrosive sublimate treatment on yield and from the experience of Jones in Vermont it is apparent that some of the injury was undoubtedly due to treatment of sprouted seed.

The influence of seed treatment on yield in Washington is rather unfavorable as may be seen from data gathered over a number of years. Practically all these tests have been with treated and untreated seed so that the influence of treatment on yield is shown. Treatment in these tests was carried out one to two weeks before planting and in some cases the tubers had begun to sprout before treatment. There is no reason to believe that the method of treatment was much different from what has been practiced in at least some of the cases of increased yields mentioned above.

Actual reduced yield from mercuric chloride seed treatment was secured in 1916 (Table 7); 1917 (Tables 5 and 12); 1922 (Tables 18 and 19); and 1923 (Tables 24 and 25). The work in 1922 was the only work carried out on infested soil. The data may be seen in the Tables referred to. Reduction in yield of as much as 38 per cent is shown in two of the tests (Tables 4 and 5).

Increased yields were secured only in the case of two tests both on clean soil: 1919 (Table 11), and 1922 (Tables 22 and 23). In each case there was quite an increase in yield from the seed that was treated over that which received no treatment.

Yields neither materially increased nor decreased were the result of seed treatment tests in four different years: 1918 (Tables 6 and 14); 1919 (Table 17); and 1923 (Tables 9, 10, 20, and 21). The first test mentioned in 1918 was on infested ground while the remainder were on clean soil.

These studies of the influence of mercuric chloride treatment on yield would seem extensive enough to show that in this state treatment does not increase yield and in many cases causes an actual decrease in total yield and also the yield of marketable tubers. The

seed grower can afford to take the decrease in yield if a cleaner product is secured. For commercial production in Washington where potatoes are grown occasionally in rotation with pasture and where soil infestation is not an item, it would seem that seed treatment is of questionable value. It is significant that increase or decrease of yield cannot be correlated with clean or infested soil. Treatment of seed tubers at different intervals throughout the storage period and subsequent effect on yield has not been studied.

Efficiency of mercuric chloride treatment. Data persented in Tables 6 and 19 show that soil contamination obliterates any effect of seed selection or seed treatment as far as control of disease in the crop is concerned. Data presented above also show that treatment is of little value from a yield standpoint and may operate to lower yields on contaminated soils. In the necessity of growing a crop of potatoes on badly infested soil or following potatoes with potatoes, the low efficiency of seed treatment would render its use of little value.

These are similar to findings in North Dakota (47) where treatment was found of no value on account of the abundance of Rhizoctonia in the soil. Soil contamination may explain lack of control secured by Selvig (66) and Selby (64). This contention is also supported by the work of Melhus and Gilman (45) who found that seed treatment tests were influenced by soil contamination.

The efficiency of this treatment has varied in the different tests that have been carried out on clean soil (44). Infected untreated seed has very consistently given a higher percentage of diseased tubers than clean seed. Treatment has also rather consistently reduced the amount of disease in a crop from infected seed. Treated infected seed has in many cases compared favorably with clean seed or seed selected for freedom from sclerotia but untreated. In nearly every case treatment has still further lowered the percentage of disease in a crop from clean or selected seed. Examination of data in Tables 4, 5, 13, 14, 15, 21, 23 and 25 shows, as stated above, that treatment does not control all the diesase carried on the seed in the form of sclerotia. If the treatment were 100 per cent efficient the treated infected seed would yield as clean a crop as clean treated seed. The data in the tables mentioned are sufficient to prove that

treatment for two hours in a solution of mercuric chloride, 4 ounces to 30 gallons water, does not kill all the sclerotia on the tubers even though the tubers have been presprinkled and kept moist for 12 to 24 hours before treatment. Treatment, then, will not offset the lack of selection nor will it prevent soil contamination where infected seed is used.

Conclusions from seed treatment studies. Certain conclusions drawn from the data in the above mentioned seed treatment studies may be collected at this point: 1. Mercuric chloride is superior to formaldehyde or other fungicides tried for the control of the Rhizoctonia disease on seed tubers. 2. Benefits of seed treatment are nullified by heavy soil infestation. In the absence of crop rotation seed treatment is of little value. 3. The efficiency of seed treatment can be increased by seed selection. 4. The returns from seed treatment will rest somewhat on whether seed or table stock is being grown and also on the amount of available land governing the frequency of cropping to potatoes. 5. Increased yields from treatment have not been secured in a large enough percentage of cases to justify treatment on the basis of yield alone. 6. On the basis of the data presented, the seed grower should always be advised to use seed treatment. Seed treatment by the commercial grower and small gardener will net returns chiefly in prevention of soil contamination and in control of other diseases carried on the tuber. 7. Seed treatment should be carried out early in the spring to avoid the injury to tubers which occurs after they have started to sprout.

Cultural Practice Studies

Diseases such as the Rhizoctonia disease which are caused by soil organisms are in many cases to be ameliorated or controlled by planting, harvesting and other cultural practices. The investigations in Washington have included studies of fertilizers and soil cleansers, spraying and planting and harvesting practices. The Netted Gem variety has been used in this phase of the investigational work. Tests were conducted under dry land culture and also under irrigation.

Soil treatments (fertilizers). The experiments in this series were carried out at Pullman on the Station Farm. The soils here in

common with those elewhere in this section of the Palouse Country are considered to be well supplied with all the elements necessary for the growth of the potato plant . Moisture is considered the limiting factor in potato production. For this reason, consistent results in yield cannot be expected from fertilizer applications. This statement is borne out by the results secured in the experiments which are discussed below.

The soil cleansing action of fertilizers or materails that in many cases seem to increase the available plant food in the soil has been demonstrated in potato scab control. Martin (38, 39, 40) on the basis of extensive experimental work advises the use of sulphur against the scab organism in the soil. The sulphur in this case was found to influence soil acidity making conditions unfavorable for the scab organism. Cyanamide is another illustration of a fertilizer useful also in the control of diseases due to nematodes as has been demonstrated by Watson (74, 75). The question of the influence of fertilizers on the Rhizoctonia disease has often been raised by growers in Washington. This has been stimulated probably by the published work on sulphur for scab control.

The results of soil treatments in the years 1917, 1918 and 1919 respectively are given in Tables 13, 14 and 15. Sulphur was included for two years replacing kainit which could not be obtained because of war conditions. Seed carrying sclerotia was used untreated and for comparison clean seed from the same seed lot was selected and given the standard treatment. These plots were on uncontaminated soil, at least no crop of potatoes was known to have been grown on the same land since it was broken from the virgin prairie.

The test in 1917 (Table 13) showed an increase of yield by acid phosphate and a slight increase of the disease as measured by sclerotia on the tubers at harvest time as compared with the check plots. The manure, lime, kainit and sodium nitrate had no noticeable effect on yield or percentage of disease. That the ground did contain some of the parasite was evidenced by the fact that the clean treated seed gave rise to a crop with roughly two thirds of the tubers bearing sclerotia. This was more disease than appeared in the tests in 1918 and 1919. A summary of the plots shows that clean seed outyielded

the diseased seed even though the seed treatment factor was introduced.

Table 13

Seed Selection and Soil Treaments for Rhizoctonia at Pullman in 1917

Plot No.	Fertilizer used		Seed	Yield in lbs. of tubers		Per cent tubers sclerotia free
	Kind	Amt. per acre		Marketable	Total	
1	Manure	20 tons	Infected	243	448	0.9
2	Manure	20 tons	Clean treated	307	390	62.6
3	Lime	1500 lbs.	Infected	331	410	0.0
4	Lime	1500 lbs.	Clean treated	321	367	67.4
5	Acid Phosphate	1200 lbs.	Infected	419	502	2.4
6	Acid Phosphate	1200 lbs.	Clean treated	443	578	43.6
7	Kainit	900 lbs.	Infected	288	364	0.7
8	Kainit	900 lbs.	Clean treated	268	360	66.5
9	Sodium nitrate	900 lbs.	Infected	235	315	2.3
10	Sodium nitrate	900 lbs.	Clean treated	285	273	73.3
11	None		Infected	230	308	3.7
12	None		Clean treated	294	363	61.5
13	None		Infected	410	465	1.3
14	None		Clean treated	268	344	77.7
15	None		Infected treated	314	406	0.6
16	None		Clean untreated	466	554	44.1
Summary even numbered plots			Clean	2652	3329	62.1
Summary odd numbered plots			Infected	2470	3218	1.5
Clean untreated seed (Plot 16)				466	554	44.1
Clean treated seed (Average all plots)				312	396	64.7
Infected untreated seed (Average all plots)				308	402	1.5
Infected treated seed (Plot 15)				314	406	0.6

The test in 1918 (Table 14) did not bear out the results of 1917. Acid phosphate did not have any effect on yield or disease. On the other hand lime caused a decrease in the disease appearing in the plot of diseased untreated seed and had an apparently beneficial effect on the yield. Sulphur had no influence on the disease

although it apparently increased the total yield of the diseased seed. Manure and sodium nitrate did not have any effect on the disease or yield.

Table 14

Seed Selection and Soil Treatments for Rhizoctonia at Pullman in 1918

Plot No.	Fertilizer used		Seed	Yield in lbs. of tubers		Per cent tubers sclerotia free
	Kind	Amt. per acre		Marketable	Total	
1	Manure	20 tons	Infected	444	663	23.4
2	Manure	20 tons	Clean treated	633	702	97.4
3	Lime	1500 lbs.	Infected	620	742	60.3
4	Lime	1500 lbs.	Clean treated	438	496	100.0
5	Acid phosphate	1200 lbs.	Infected	401	466	0.6
6	Acid phosphate	1200 lbs.	Clean treated	421	458	99.3
7	Sulphur	900 lbs.	Infected	632	770	3.5
8	Sulphur	900 lbs.	Clean treated	452	485	93.5
9	Sodium nitrate	900 lbs.	Infected	428	553	0.0
10	Sodium nitrate	900 lbs.	Clean treated	544	596	97.9
11	None		Infected	590	658	20.0
12	None		Clean treated	555	606	100.0
13	None		Infected	399	486	0.8
14	None		Clean treated	352	394	78.9
15	None		Infected treated	365	425	12.4
16	None		Clean untreated	355	394	76.9
Summary even numbered plots			Clean	3750	4131	93.0
Summary odd numbered plots			Infected	3879	4763	1.5
Clean untreated seed (Plot 16)				355	394	76.9
Clean treated seed (Average all plots)				485	534	95.3
Infected untreated seed (Average all plots)				502	520	15.5
Infected treated seed (Plot 15)				365	425	12.4

The test in 1919 (Table 15) did not show very conclusive results. The sulphur plot contained more disease than the other plots and more than one of the check plots immediately beside it. If the fertilizer operated to increase the disease there may have been some

influence from sulphur being carried by wind from the treated plot beside it, but such possibility is rather small. It is certain that some influence was operative in these two plots which were on the end of the series of plots to cause an increase of percentage of disease in the harvested crop. The series of experiments on soil treatments does not show any promise of control of the Rhizoctonia disease by

Table 15

Seed Selection and Soil Treatments for Rhizoctonia at Pullman in 1919

Plot No.	Fertilizer		Seed	Yield in lbs. of tubers		Per cent tubers sclerotia free
	Kind	Amt. per acre		Market-able	Total	
1	Manure	20 tons	Infected	168	236	9.6
2	Manure	20 tons	Clean treated	228	280	76.5
3	Lime	1500 lbs.	Infected	203	280	7.4
4	Lime	1500 lbs.	Clean treated	234	287	93.4
5	Acid phosphate	1200 lbs.	Infected	210	282	8.6
6	Acid phosphate	1200 lbs.	Clean treated	326	274	94.7
7	Sulphur	900 lbs.	Infected	307	409	14.8
8	Sulphur	900 lbs.	Clean treated	197	271	22.1
9	Sodium nitrate	600 lbs.	Infected	229	323	11.5
10	Sodium nitrate	600 lbs.	Clean treated	215	283	86.1
11	None		Infected	202	269	3.3
12	None		Clean treated	293	357	98.8
13	None		Infected	218	302	6.3
14	None		Clean treated	200	262	28.5
15	None		Infected treated	401	479	59.5
16	None		Clean untreated	191	274	60.0*
Summary even numbered plots			Clean	1884	2288	80.0
Summary odd numbered plots			Infected	1938	2580	13.8
Clean untreated seed (Plot 16)				191	274	60.0
Clean treated seed (Average all plots)				242	488	71.4
Infected untreated seed (Average all plots)				220	300	8.8
Infected treated seed (Plot 15)				401	470	59.5

*Estimated because of lost data.

soil treatments. No very positive evidence is shown of either benefit or harm from the application of any of the fertilizers used. Additional work is desirable to show what effects fertilizers including lime might have under irrigated conditions and also in the case of some of the acid soils devoted to potatoes in Western Washington.

These results are very similar to those secured by Gussow and Eastham (29) who did not get consistent results from soil treatment, having used sulphur in their experiments. Appel (2) reports reduction of Rhizoctonia in acid forest soils by the application of lime. Soils used for the experiments at Pullman were neutral and perhaps beneficial effects from lime should not be expected. One season's results only showed any reduction in disease that might be attributed to the action of lime. The effect of sulphur on the Rhizoctonia has been shown by Morse and Shapovalov (48) who found that a 500 pound applicatoin of sulphur increased the disease 20-30 per cent. This percentage of increase was less than shown in Table 15 for the sulphur plot. However, the influence of sulphur was nil in the experiments carried out in 1918 (Table 14).

Work in Washington and that reported by other investigators does not offer any promise of benefit from soil treatments for Rhizoctonia on ordinary soils. Lime on acid soils to correct soil acidity and the avoidance of sulphur or other fertilizers producing acid soils is advisable judging from the work mentioned above dealing with such soils.

Spraying practices. Bordeaux spray has been used freely in the Eastern United States for the control of parasitic foliage diseases. In the absence of these diseases the spray in many instances has been found to increase yields. This has been attributed to the stimulatory action of the copper spray. To test out the possibility of benefit from this spray under Washington conditions experiments were conducted at Pullman and Yakima using the Netted Gem variety. The plots at Pullman were on clean soil while the soil of the plots in the Yakima Valley undoubtedly was infested although it had not grown a crop of potatoes for a number of years. Seed was selected in each case that showed an abundance of sclerotia. Clean seed from the same lot was selected and a portion of each lot used at

Yakima was given the standard corrosive sublimate treatment. Unsprayed plots and plots sprayed twice were run at Pullman. At Yakima unsprayed plots were compared with plots sprayed once and other plots receiving two sprays during the season. At digging time records were taken for yield and freedom from sclerotia.

Table 16

Bordeaux Spray Applied to Potatoes at Yakima, 1918

Plot No.	Times sprayed	Seed used		Yield in lbs. of tubers		Per cent tubers sclerotia-free
		Selection	Treatment	Marketable	Total	
1	0	Clean	Untreated	1276	1858	0.0
2	1	Clean	Untreated	1103	1495	0.0
3	2	Clean	Untreated	1858	2437	1.3
4	0	Infected	Untreated	1121	2136	2.7
5	1	Infected	Untreated	1418	1969	7.2
6	2	Infected	Untreated	1176	1979	0.8

At no time in the last ten years has it been necessary to spray for foliage diseases in either of these regions. The tip burn or hopper-burn disease is not troublesome so that any action of the spray would be limited to its stimulatory action on the plant except in so far as flea beetle injury is limited. The experiments were carried out in the Yakima Valley during 1918 and 1919 and at Pullman during 1919. Data for the 1918 work at Yakima is given in Table 16. Soil contamination is indicated by the percentage of disease in the plots planted with clean seed. Positively no beneficial results can be seen to have resulted from the spraying, either in increase of yield or freedom from disease. The yields are so variable between plots that the increased yield in Plot 3 cannot be attributed to the spray applied. This experiment was duplicated for the Yakima Valley in 1919 with no more favorable results than were secured in 1918. On the basis of these tests Bordeaux spray cannot be recommended for the irrigated potato section of Washington either from the standpoint of yield or any protective effect it might have against the attack of soil parasites such as Rhizoctonia.

Work at Pullman in 1919 gave but little better results. The data for this test are recorded in Table 17. The yields on the sprayed plots show increases over yields in the unsprayed plots. The variation in yield between plots, even those that may be comparable, is excessive and although there is apparently some increase of yield that may be attributed to the spray, additional work is advisable before the spray could be recommended from the yield standpoint. In respect to freedom from disease no influence of the spray can be noted. In fact selection of seed is seen to have greater influence on the percentage of disease in these plots than any other factor. That soil infestation was light is evidenced by the high percentage of clean tubers harvested at Pullman in comparison with the plots at Yakima. The data suggest the need for additional work at Pullman or in the dry land culture belt of Eastern Washington before we can condemn or recommend use of Bordeaux where parasitic foliage diseases are absent and where tip burn or hopperburn is not troublesome.

Table 17

Bordeaux Spray Applied to Potatoes at Pullman, 1919

Plot No.	Times sprayed	Seed used		Yield in lbs. of tubers		Per cent tubers sclerotia-free
		Selection	Treatment	Marketable	Total	
1	0	Clean	Untreated	68	84	79.7
2	2	Clean	Untreated	70	94	87.5
3	0	Clean	Treated	68	96	81.9
4	2	Clean	Treated	77	104	41.5
5	0	Infected	Untreated	62	88	4.9
6	2	Infected	Untreated	65	113	4.5
7	0	Infected	Treated	76	124	4.1
8	2	Infected	Treated	103	123	57.5

It is interesting to compare these results with results obtained by workers in other states. As result of tests covering twenty-one years in Vermont, Lutman (36,37) presents data showing an increased yield of from 18-215 with an average of 64 per cent from Bordeaux spray. During six years of this peroid the increases were secured in the absence of late blight. Stewart, French and Sirrine

(69) show increased yields in tests covering a ten year period in New York State. They attribute the larger part of the increase to the control of the late blight. Stewart (68) shows in the results of work in 1914 that increased yield may not always be secured from spray in New York although his average results do show an increase of from 5 to 8 per cent. The season of 1914 in New York was one characterized by freedom from foliage diseases.

Increased yields from spraying in New Jersey were found by Martin (41) to be influenced by variety. Tests with Irish Cobbler over a period of ten years showed an average increase of 28 bushels per acre from Bordeaux spray. Four years of this test in the absence of late blight showed an increased yield of 42 bushels. Tests by the same worker with the American Giant variety showed no increased yields in the absence of late blight. Bisby and Tolaas (4) in reporting work in Minnesota covering a period of sixteen years in the absence of late blight show an average increase of yield from spraying at the University Farm, of 30 bushels for late varieties and 27 bushels for early varieties. Bailey (3) also shows in a one year test in Oregon an increase from spraying in the absence of late blight. Increased yields are reported for other states (5, 6) but in general from those regions where late blight is common or sometimes occurs. In those regions spraying is generally profitable even though late blight does not occur.

Less favorable results from spraying with Bordeaux in the absence of late blight or other foliage diseases are secured (5, 6) in those regions where these diseases are rare or do not occur. There is apparently something in the climatic conditions unfavorable to blight which also limits the stimulatory action (8) of the spray. On the basis of work in regions somewhat similar to the potato producing sections of Washington consistent results from the use of Bordeaux should not be expected. It is very doubtful if the application of Bordeaux will prove commercially profitable anywhere in Washington except in the more humid section of Western Washington where late blight is occasionally prevalent and in those situations where flea-beetle injury becomes serious.

Planting and Harvesting practices. Time of planting and harvesting the potato have a marked influence on the amount of the Rhizoctonia disease in the resulting crop. To evaluate these factors experiments were carried out at Pullman for Eastern Washington conditions and at Prosser for conditions in the irrigated valleys. The same stock of the Netted Gem variety was used each season at the two stations. Plantings were made at two week intervals, or, on the first and fifteenth of each month. At Pullman the first planting was made as soon as the soil could be worked and continued past the time when a crop could be expected to mature.

The seed was divided into two lots, infected and clean tubers or tubers free from sclerotia. Half of each lot was given the standard corrosive sublimate treatment. Only enough was cut at any one time to make the required planting. At Pullman the seed lots were kept in common storage until used. At Prosser the unused portion of the seed stock was kept in cold storage and only enough withdrawn at any one time to make the plantings. The seed in each case was not free from mosaic but practically the same percentage of disease appeared in each plot so that it is felt that results are comparable.

Records were kept of the air temperatures and soil temperature in the plots at a depth of six inches. Mean maximum and mean minimum air and soil temperatures are recorded in Table 26. The percentage of stand was taken and at harvest the yield of marketable tubers and the total yield of all tubers was recorded. Freedom from disease was also recorded for the marketable tubers from each plot. At each station the plots were all dug at practically the same time. that is after frost had cut down most of the vines. It was originally intended to dig half of each plot upon ripening and half later in the fall but the date of ripening for the earliest plots was so near the time for the first frost that this was not done. The data therefore, will show the influence only of variation in planting date

Table 18

Influence of Date of Planting on Rhizoctonia at Pullman, 1922

Plot	Date planted	Seed	Per cent stand	Yield in lbs.		Per cent tubers clean
				Marketable	Total	
A	April 22	Clean untreated	96.2	68	110	0.9
		Clean treated	95.0	71	116	5.6
		Infected untreated	96.0	91	130	5.0
		Infected treated	95.0	74	115	2.5
B	May 6	Clean untreated	97.0	82	97	1.6
		Clean treated	97.0	95	128	2.4
		Infected untreated	94.1	92	125	2.9
		Infected treated	99.0	97	123	2.8
C	May 20	Clean untreated	100.0	85	106	2.3
		Clean treated	95.1	91	120	2.0
		Infected untreated	96.1	123	153	3.6
		Infected treated	94.1	96	143	5.0
D	June 3	Clean untreated	97.1	65	105	10.3
		Clean treated	90.3	78	110	11.8
		Infected untreated	98.0	106	144	8.9
		Infected treated	98.0	84	121	10.1
E	June 17	Clean untreated	93.2	85	106	11.3
		Clean treated	83.6	79	106	16.5
		Infected untreated	95.9	93	123	10.6
		Infected treated	81.7	83	111	18.4
F	July 1	Clean untreated	88.5	76	116	22.7
		Clean treated	80.0	78	109	41.5
		Infected untreated	75.2	64	100	33.3
		Infected treated	75.2	57	89	42.5

The data collected in the test at Pullman in 1922 are presented in Table 18 and are summarized in Table 19. The plots were on contaminated ground and this counteracted almost entirely any influence of seed selection or seed treatment. This is especially true of the percentage of disease appearing in each series of plots. As will be seen the last planting produced the cleanest crop and was but little below the other plots in point of total yield although the perecntage of unmarketable tubers was slightly higher than in some of the eariler planted plots. The influence of temperature on the percentage of disease in the harvested crop is clearly seen. This is in agreement with the findings of Richards (70). The summary of data in Table 19 shows that treatment has some effect on the percentage of disease in the crop even on infested ground. Treatment lowered slightly the total yield and the yield of marketable tubers while all effect of seed selection was lost.

Table 19

Summary of Data in Table 18

Seed	Yield in lbs.		Per cent tubers clean
	Marketable	Total	
Clean untreated, all plots	460	640	8.1
Clean treated, all plots	492	690	13.3
Infected untreated, all plots	565	772	10.7
Infected treated, all plots	487	699	13.5
Clean untreated and treated, all plots	652	1330	10.7
Infected untreated and treated, all plots	1052	1471	12.1
Untreated clean and infected, all plots	1025	1412	9.4
Treated clean and infected, all plots	979	1389	13.4

Table 20

Influence of Date of Planting on Rhizoctonia at Pullman, 1923

Plot	Date planted	Seed	Per cent stand	Yield in lbs.		Per cent tubers clean
				Market-able	Total	
A	April 14	Clean untreated	97.0	156	193	4.5
		Clean treated	99.0	130	168	1.0
		Infected untreated	98.0	103	138	44.5
		Infected treated	100.0	155	177	0.4
B	April 28	Clean untreated	99.0	139	168	97.2
		Clean treated	98.0	118	133	100.0
		Infected untreated	98.0	94	152	49.0
		Infected treated	100.0	177	204	96.5
C	May 12	Clean untreated	99.0	1 5	152	44.2
		Clean treated	100.0	176	191	94.8
		Infected untreated	99.0	166	203	67.0
		Infected treated	100.0	184	203	91.7
D	May 26	Clean untreated	100.0	137	152	82.8
		Clean treated	100.0	165	190	90.2
		Infected untreated	96.1	114	149	48.6
		Infected treated	98.0	136	165	88.8
E	June 9	Clean untreated	97.0	105	130	63.0
		Clean treated	100.0	115	135	89.8
		Infected untreated	96.1	98	134	26.4
		Infected treated	100.0	126	150	91.5
F	June 23	Clean untreated	98.0	76	111	81.3
		Clean treated	99.0	84	115	20.3
		Infected untreated	99.0	90	126	84.5
		Infected treated	99.0	120	138	92.1
G	July 7	Clean untreated	77.9	42	59	63.2
		Clean treated	67.9	54	63	84.4
		Infected untreated	71.1	65	91	6.7
		Infected treated	51.9	32	41	91.9

Data for the second year of the experiment at Pullman in 1923 are recorded in Table 20 and summarized in Table 21. These plots were on clean soil and were run in a parallel fashion to those in 1922. Percentage of stand and yield will be seen to have dropped sharply in the last two planting dates. From the standpoint of freedom from disease and yield the plantings in May are superior to those made earlier or later. The percentage of stand is very satisfactory except in the case of the last date of planting.

Table 21

Summary of Data in Table 20

Seed	Yield in lbs.		Per cent tubers clean
	Marketable	Total	
Clean untreated, all plots	781	966	50.4
Clean treated, all plots	844	997	81.8
Infected untreated, all plots	731	993	55.6
Infected treated, all plots	931	1080	70.1
Clean untreated and treated, all plots	1625	1963	66.1
Infected untreated & treated, all plots	1662	2073	62.8
Untreated, clean and infected, all plots	1512	1959	53.0
Treated clean and infected, all plots	1775	2077	75.9

Table 22

Influence of Date of Planting on Rhizoctonia at Prosser, 1922

Plot	Date planted	Seed	Per cent stand	Yield in lbs. Marketable	Yield in lbs. Total	Per cent tubers clean
A	April 1	Clean untreated	92.0	55	164	68.2
		Clean treated	92.5	57	207	93.8
		Infected untreated	95.5	37	167	6.6
		Infected treated	91.0	61	200	42.5
B	April 15	Clean untreated	95.0	51	186	60.8
		Clean treated	94.0	27	156	96.3
		Infected untreated	95.5	21	165	16.3
		Infected treated	96.0	28	190	41.1
C	May 1	Clean untreated	93.0	16	123	62.5
		Clean treated	93.0	35	199	69.6
		Infected untreated	94.5	31	137	14.0
		Infected treated	93.0	28	209	52.5
D	May 15	Clean untreated	96.5	27	121	70.4
		Clean treated	85.0	56	179	92.8
		Infected untreated	91.0	24	117	8.3
		Infected treated	69.0	35	96	88.5
E	June 1	Clean untreated	92.5	53	140	87.0
		Clean treated	91.0	97	234	93.8
		Infected untreated	91.5	55	141	5.5
		Infected treated	88.5	54	216	92.5
F	June 15	Clean untreated	93.5	86	154	88.3
		Clean treated	88.5	102	172	95.5
		Infected untreated	93.0	88	155	11.9
		Infected treated	93.5	103	220	95.6
G	July 1	Clean untreated	88.0	107	172	87.0
		Clean treated	92.0	81	191	95.7
		Infected untreated	87.5	107	175	33.6
		Infected treated	90.0	130	204	87.9
H	July 15	Clean untreated	91.5	65	173	86.2
		Clean treated	89.0	118	175	94.0
		Infected untreated	75.0	97	161	29.9
		Infected treated	71.5	50	119	94.0

The test at Prosser in 1922 was with the same seed as used at Pullman in 1922 and was carried out in the same way. The data are presented in Table 22 and summaried in Table 23. The plots were all of equal size so that yields are comparable. The percentage of stand was higher in the later plantings probably due to more adequate irrigation. Shortage of water checked the early planted plots and undoubtedly accounts for the large percentage of unmarketable tubers in these plots. The later planted plots showed greater freedom from disease in the harvested crop over what was secured in the earlier planted plots.

Table 23
Summary of Data in Table 22

Seed	Yield in lbs.		Per cent clean tubers
	Marketable	Total	
Clean untreated, all plots	460	1233	80.3
Clean treated, all plots	573	1514	93.0
Infected untreated, all plots	460	1220	19.7
Infected treated, all plots	490	1454	80.1
Clean untreated and treated, all plots	1033	2747	86.6
Infected untreated and treated, all plots	950	2674	49.9
Untreated clean and infected, all plots	920	2443	50.0
Treated clean and infected, all plots	1063	2968	86.5

Table 24

Influence of Date of Planting on Rhizoctonia at Prosser, 1923

Plot	Date planted	Seed	Per cent stand	Yield in lbs. Marketable	Yield in lbs. Total	Per cent tubers clean
A	April 25	Clean untreated	98.0	151	330	85.0
		Clean treated	97.5	147	273	99.0
		Infected untreated	97.0	155	298	32.5
		Infected treated	96.0	159	257	87.0
B	May 1	Clean untreated	98.5	183	315	88.0
		Clean treated	98.0	183	294	98.5
		Infected untreated	99.0	204	303	37.0
		Infected treated	99.0	216	325	95.5
C	May 15	Clean untreated	97.0	190	321	88.5
		Clean treated	97.0	167	276	93.0
		Infected untreated	100.0	177	284	51.0
		Infected treated	99.5	165	262	95.5
D	June 1	Clean untreated	100.0	176	265	94.5
		Clean treated	98.0	158	239	99.5
		Infected untreated	98.0	119	257	37.0
		Infected treated	99.5	124	232	95.0.
E	June 15	Clean untreated	98.0	171	235	92.0
		Clean treated	97.0	141	227	100.0
		Infected untreated	96.5	214	265	47.0
		Infected treated	92.5	180	252	94.5
F	July 1	Clean untreated	97.0	175	210	96.0
		Clean treated	92.0	148	190	97.5
		Infected untreated	96.5	170	225	85.0
		Infected treated	98.5	205	268	98.0
G	July 15	Clean untreated	92.5	118	165	99.0
		Clean treated	91.5	109	141	95.5
		Infected untreated	92.0	128	182	86.5
		Infected treated	90.5	120	159	96.5

The second year's work at Prosser in 1923 was again with the same seed as used at Pullman for that year. Data for 1923 are collected in Table 24 and summarized in Table 25. The first planting was not made as early as in 1922, thereby eliminating one of the planting dates. The percentage of disease-free tubers in the harvestrd crop will be seen to have steadily improved in the later plantings showing that the plantings extended past the most favorable date for the season. The percentage of stand was quite satisfactory for all but the last planting date.

Table 25

Summary of Data in Table 24

Seed	Yield in lbs.		Per cent tubers clean
	Marketable	Total	
Clean untreated, all plots	1164	1841	91.9
Clean treated, all plots	1053	1640	97.6
Infected untreated, all plots	1167	1814	53.9
Infected treated, all plots	1169	1755	94.6
Clean untreated and treated, all plots	2217	3481	94.7
Infected untreated and treated, all plots	2336	3569	74.1
Untreated clean and infected, all plots	2331	3655	72.7
Treated clean and infected, all plots	2222	3395	96.1

Early planting is seen to afford favorable conditions for the developing of the maximum amount of disease in the crop. These results are similar to those secured by Rolfs (59) who observes that late planting is frequently advantageous from the disease standpoint. The time of harvesting potatoes is also important in any serious attempt to limit the amount of disease in the crop according to the findings of Roze (61) and Bisby, Hinham, and Groh (7). Unfortunately these investigators do not submit temperature data so that comparisons might be made. The temperatures at Pullman and Prosser during the fall are favorable to the development of Rhizoctonia as seen in the data presented in Table 26. Growers have offered observational data which gives support to the contention that crops left in the ground until after the advent of fall rains will accumulate sclerotia rather rapidly.

Table 26

Mean Soil Temperatures on the Potato Plots during the Growing Seanson at Pullman and Prosser, 1922 and 1923

Period	1922				1923			
	Pullman		Prosser		Pullman		Prosser	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Apr. 16-30 ...					51.9*	42.9*	54.6*	51.6*
May 1-15			53.3*	49.8*	57.8	48.4	59.4	56.6
May 16-31 ...	62.6	52.5	61.2	56.1	60.4	50.6	61.6	58.1
June 1-15 ...	73.4	61.6	72.8	68.0	62.2	52.2	63.0	59.9
June 16-30 ..	77.4	65.3	76.3	70.9	64.6	55.9	69.3	65.8
July 1-15	78.0	66.9	78.3	73.9	72.6	64.2	75.8	71.5
July 16-31 ...	79.2	65.4	75.3	71.1	73.3	66.1	79.8	75.7
Aug 1-15	76.0	64.6	72.5	69.3	71.2	63.7	75.0	72.4
Aug. 16-31 ...	75.0	60.8	72.3	69.1	71.8	65.8	74.7	71.8
Sept. 1-15 ...	67.6	56.2	69.8	66.6	69.5	63.8	73.3	70.4
Sept. 16-30...	62.6	54.3	66.0	63.2	57.8	54.2	65.2	62.6
Oct. 1-15.....	54.5*	46.7*	57.2	54.7	61.0*	56.2*	59.6	67.4
Oct. 16-31....			52.8	50.8			51.6	49.3
Nov. 1-14			42.5*	41.2*			48.7*	46.7*

*Computed on less than two week period.

The above studies indicate that: (1) Seed growers in Washington would harvest cleaner crops if plantings were made as late as possible and yet mature the crop before the cool wet season of the fall. Requirements for seed certification with respect to Rhizoctonia would be more easily met in this way. (2) Growers of commercial stock should plant at the time when the largest yield and greatest freedom from disease are insured. This will vary with the different localities but may be later in irrigated sections than in Eastern Washington. This planting date for the main crop will agree quite closely with the date when corn may safely be planted in a locality. (3) Growers of early market stock will sacrifice the advantage, in respect to disease, of late planting and yet by rotation, seed selection, and seed treatment be able to attain a reasonable amount of disease control.

HOSTS FOR RHIZOCTONIA IN WASHINGTON

A consideration of the Rhizoctonia disease of the potato is not complete without some attention to other hosts upon which the parasite may be found. As mentioned above some of the less susceptible garden crops are often seriously affected with Rhizoctonia when they follow potatoes. These and other hosts including many wild plants (weeds), serve to keep the parasite alive through the rotation. The data presented below have been accumulated in the records of the Department of Plant Pathology since 1915 and are based entirely on detailed field and laboratory examination.

Cultivated Plants Harboring Rhizoctonia

The cultivated plants upon which Rhizoctonia has been found in Washington are listed in Table 27. All plants listed have had mycelium on the root system either apparent to the naked eye or found on microscopic examination. No systematic search has been made but these cases have been noted in field trips or have been found on plants sent to the Division of Plant Pathology for diagnosis. It is certain that a careful examination of many other plants growing in and about potato fields would show Rhizoctonia mycelium on the root system and if conditions were right more instances of the Corticium stage could undoubtedly be found. As will be noted, sclerotia have been found on several hosts.

Table 27

Cultivated Hosts for Rhizoctonia Solani and Corticium Vagum in Washington

Host	Stage of parasite found			Nature of injury
	Mycelium	Sclerotia	Corticium	
Aster	†	*	*	Root rot
Bean	†	†	†	Stem and root rot
Beet	†	†	†	Feeding root injury
Buckwheat	†	*	*	Feeding root injury
Cabbage	†	†	*	Damping off, stem rot
Carnation	†	*	*	Crown and stem rot
Carrot	†	†	†	Root rot
Cauliflower	†	†	*	Damping off, stem rot
Celery	†	*	*	Feeding root injury
Corn	†	†	*	Feeding root injury
Cucumber	†	*	*	Damping off, wilting
Eggplant	†	†	*	Feeding root injury
Geranium	†	*	*	Root injury
Ginseng	†	*	*	Associated with scab
Golden Seal	†	*	*	Foot rot seedlings
Horseradish	†	†	*	Root rot
Iris	†	*	*	Root rot
Kale	†	*	*	Root rot
Lettuce	†	*	*	Damping off
Loganberry	†	*	*	Injury to new shoots
Mangel	†	*	*	Damping off, stem rot, root rot
Oats	†	*	*	Mycelium on roots
Onion	†	*	*	Root injury
Parsnip	†	†	†	Feeding root injury
Peas	†	*	*	Stem and root rot
Potato	†	†	†	Stem, root and tuber rot, aerial tubers, etc.
Radish	†	†	†	Root injury
Raspberry				
Blackcap	†	*	*	Injury to new tips
Rhubarb	†	*	†	Root injury
Salsify	†	*	*	Root injury
Spinach	†	*	†	Stem and root rot
Strawberry	†	*	†	Associated with root rot
Sunflower	†	*	*	Root injury
Sweet clover	†	*	*	Root injury
Sweet pea	†	*	*	Root rot
Tomato	†	†	†	Root rot
Turnip	†	†	†	Root rot
Vetch	†	*	*	Root rot
Watermelon	†	*	*	Root rot

†Presence of stage indicated.
*Absence of stage indicated.

Most of the vegetable crops and many field crops are numbered among the hosts for Rhizoctonia. Of these beans, carrots, onions, peas and radish, have been severely attacked following a crop of diseased potatoes. These crops and probably many others enable the parasite to maintain an active parasitic existence. A very logical solution to this problem would be the elimination of potato growing from areas where short rotations are followed and from restricted areas cropped to very susceptible hosts.

The attack of Black Cap Raspberry and Loganberry is unusual and has occurred only in Western Washington. The Rhizoctonia on strawberry has accompanied a black-root condition but no proof has been obtained of causal relationship except that of association. The fungus on buckwheat, corn, ginseng, golden seal, eggplant, geramium, horesradish, iris, oats, parsip, rhubarb, sunflower, sweet clover, vetch and watermelon was in most cases not attendant with any very noticeable effect on the plant. As noted above, mycelium, sclerotia and the Corticium stages may be abundant on any plant without apparent injury. However, the presence of the parasite on these hosts indicates infested soil and a greater or less amount of injury is bound to occur.

Wild Plants Harboring Rhizoctonia

It is interesting to note the ocurrence of the sterile and spore stages of this parasite on some wild hosts that have been found in various locations, some not in contact with potato fields. These hosts are listed in Table 28. No attempt has been made to determine the amount of injury suffered by the wild plants harboring Rhizoctonia. Neither have cross-inoculations been made to determine experimentally the actual part wild hosts play in the perpetuation of the parasite. However, the occurrence of Rhizoctonia on wild hosts may well be considered a menace in the control of the disease in cultivated crops.

Table 28

Wild Hosts for Rhizoctonia Solani and Corticium Vagum in Washington

Host	Stage of parasite found	
	Rhizoctonia	Corticium
Black bindweed, **Polygonum convolulus** L.	†	†
Canada Thistle, **Cirsium arvense** (L) Scop.	†	†
Dandelion, **Taraxacum erythrospermum**	†	*
Andrz.	†	†
Dogbane, **Apocynum cannabinum** L.	†	*
Dog fennel, **Anthemis cotula** L.	†	*
Feverfew, **Chysanthemum parthenum** Bernh	†	*
Field chamomile, **Anthemis arvensis** L.	†	†
Lamb's quarters, **Chenopodium album** L.	†	*
Low amaranth, **Amaranthus blitoides** Wats.	†	†
Mallow, **Malva rotundifolia** L.	†	†
Pigweed, **Amaranthus retroflexus** L.	†	†
Plantain, **Plantago major** L.	†	*
Shepherds purse, **Bursa bursa-pastoris**	†	†
(L) Weber	†	†
Thistle, **Cirsium** sp.	†	*
Vetch, **Vicia** sp.	†	*

†Presence of stage indicated.
*Absence of stage indicated.

SUMMARY

Rhizoctonia is indigenous to western soils and persists under cultivation as a parasite on many hosts and as a saprophyte on plant remains in the soil. Widespread contamination of the soil and the consequent occurrence of the fungus on potatoes in severe form serves to place the Rhizoctonia disease a close second in importance to the virus diseases among the troubles of potatoes.

Rhizoctonia attacks the plant at all stages. Direct injury is confined to the root system or other subterranean structures. Probably the most important injury is caused by death of feeding roots. Stem cankers disturb the nutrition of the plant and lead to abnormal location and off-type of tubers. Injury to tubers serves to lower their qualiay for seed and table use. Yield of marketable tubers is directly and indirectly influenced by the disease. Symptoms on the top are such as might be expected to result from disturbed nutrition of the plant. Symptoms such as rosette, giant hill and other abnormalities of top may accompany severe Rhizoctonia disease on potatoes but yet have no relation to the disease other than association. The Rhizoctonia disease on potatoes is of distinct detriment to many crops following potatoes because of the virulence of the parasite left in the soil by a diseased potato crop.

Seed selection affords one means of controlling the Rhizoctonia disease. The selection of seed free from sclerotia is of value in plantings made on soils reasonably free from virulent strains of the fungus. Seed selection is worthy of attention by the seed grower wishing to prevent serious soil infestation by the parasite. The above studies have shown that selection is practically as efficient as seed treatment in limiting disease in the potato crop. Due to lowering of yield by seed treatment, seed may be sorted and disinfection employed for only the infected portion of the seed stock. Th value of virus-free seed stocks will limit the use of seed selection alone.

Seed treatment with mercuric chloride is employed to kill the resting form of Rhizoctonia, the sclerotia, on the seed tubers. It is rarely 100 per cent efficient but is advisable for seed growers and

others to prevent fouling of the soil by a virulent strain of the parasite and to insure the largest crop of disease-free tubers. Seed treatment is most efficient when employed with seed selection. Both are equally useless when plantings are made on seriously infested soils. Treatment of sprouted tubers causes injury leading to reduced yield in the resulting crop although a higher percentage of the tubers will be disease free. Inoculum carried into the soil on the seed is more virulent than the fungus already in the soil which fact makes the use of seed selection and seed treatment imperative in any serious attempt to control the disease. The data presented do not justify shortened periods of treatment or the replacement of corrosive sublimate by other fungicides.

Studies of cultural practices have shown that the date of planting and harvesting a crop of potatoes will influence the amount of disease in the harvested crop. Lower temperatures and favorable moisture conditions at the beginning and end of the growing season account for this increase of the disease in early plantings and on tubers left in the soil until the advent of cool moist weather of the Fall. In general planting potatoes at about the same time corn may be planted seems to be the most advantageous from the standpoint of yield and freedom from disease. Spraying practices and soil temperatures have not been of much value in the control of Rhizoctonia on good agricultural soils. Special situations may demand special measures but for most areas in Washington, control of the disease must be by some of the means suggested other than by soil treatments or by application of spray to the growing plant. Planting and harvesting practices, together with seed selection and treatmet offer the most promise of controlling the disease on the crop and of the prevention of soil infestation.

Rhizoctonia attacks a wide range of cultivated and wild hosts. These undoubtedly play a part in the perpetuation of the parasite. Many of the cultivated plants are not severely injured except in cases where they follow a crop of potatoes. This emphasizes the need for control of Potato Rhizoctonia especially in restricted areas where these susceptible crops must be grown in succession to the potato.

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